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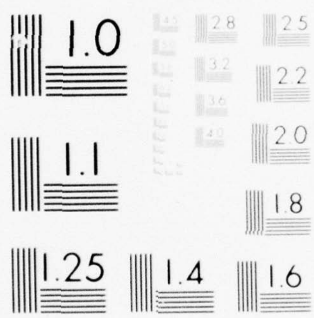

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INTERIM REPORT N-26
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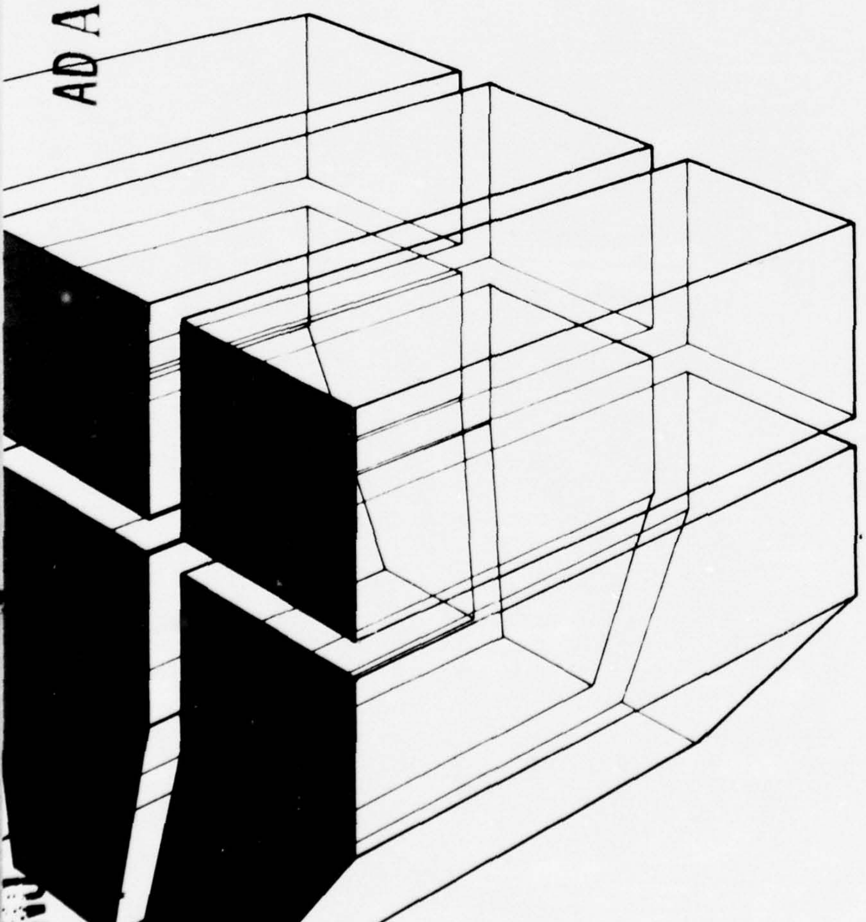
RECOMMENDED DESIGN CRITERIA FOR WASTEWATER TREATMENT AT PROPOSED CONSOLIDATED TACTICAL VEHICLE WASH FACILITY, FORT DRUM, NY



by
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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: INTERIM REPORT N-26
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) RECOMMENDED DESIGN CRITERIA FOR WASTEWATER TREATMENT AT PROPOSED CONSOLIDATED TACTICAL VEHICLE WASH FACILITY, FORT DRUM, NY.
5. TYPE OF REPORT & PERIOD COVERED: (9) INTERIM rept.,
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10) L. J. Benson, M. Staub, R. Fileccia, J. Matherly
8. CONTRACT OR GRANT NUMBER(s): IAO NYD 76-140(M)

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
P.O. Box 4005
Champaign, Illinois 61820

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS:
U.S. Army Engineer District, New York
26 Federal Plaza
New York, NY 10007

12. REPORT DATE: (11) July 1977
13. NUMBER OF PAGES: 65

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 64p.
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

(14) CERL-IR-N-26

DDC
AUG 10 1977
C

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

wastewater treatment
centralized vehicle washing
intermittent sand filters

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tracked vehicle washrack discharges were surveyed at Fort Drum, NY, to determine design criteria for wastewater treatment at a proposed consolidated tactical vehicle wash facility. These design criteria include recommended sizing of the various treatment components as indicated by the characteristics of the wastewater analyzed during the study. Wastewater treatment components include a sedimentation basin equipped for mechanical free oil removal followed by a flow equalization basin and intermittent sand filtration.

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FOREWORD

This study was conducted for the New York District, U.S. Army Corps of Engineers, under Intra-Army Order NYD 76-140(M) by the Environmental Engineering Team (ENE), Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL).

Valuable contributions of S. Kloster, V. Singh, A. Ostrofsky, and H. Becker of CERL, and the assistance of H. Hager, Chief of Utilities, Fort Drum, are acknowledged. Mr. W. J. Mikucki is Chief of ENE, and Dr. R. K. Jain is Chief of EN. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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RECOMMENDED DESIGN CRITERIA FOR
WASTEWATER TREATMENT AT PROPOSED
CONSOLIDATED TACTICAL VEHICLE WASH
FACILITY, FORT DRUM, NY

1 INTRODUCTION

Background

During the summer of 1976, the U.S. Army Construction Engineering Research Laboratory (CERL) conducted a comprehensive study on improving treatment facilities for wastewaters produced by Army vehicle washing operations at Fort Drum, NY. The large volume of potable water used for this operation and the characteristics of the wastewater produced subject these discharges to Federal regulation. The U.S. Environmental Protection Agency (USEPA) issued a National Pollution Discharge Elimination System (NPDES) discharge permit to Fort Drum which required both immediate monitoring and eventual treatment of washrack wastewater discharges. (Appendix A provides details about the USEPA permit requirements.)

To effect compliance with these requirements and to improve Army vehicle washing operations, CERL surveyed Fort Drum in 1975[1] and recommended construction of a new centralized wash facility. Recommendations from this study were based on a comparison of effective upgrading of existing facilities versus construction of new facilities that would meet USEPA permit requirements. (Appendix B contains a general description and an operational schematic of the proposed facility.) The recommendations included a need to establish final design criteria for the proposed wastewater treatment system through pilot-scale data collection and evaluation. Subsequently, the New York District of the Corps of Engineers requested that this design information be developed or that alternative solutions be developed if the proposed concept was not feasible.

Purpose

The purposes of this study were (1) to determine design criteria for an intermittent sand filtration washrack wastewater treatment system which would meet present USEPA requirements for wastewater

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[1] *Vehicle Washing Operations and Wastewater Discharges, Fort Drum, NY, Findings and Recommendations*, CERL Technical Report E-80/ADA026173 (Construction Engineering Research Laboratory [CERL], June 1976).

discharges and (2) to provide a system with sufficient flexibility to meet future USEPA water quality standards.

Approach

The results of this study were obtained from a pilot-scale study at Fort Drum which used intermittent sand filters in conjunction with a wastewater collection and pretreatment system. Filter operation was monitored to develop design criteria for full-scale treatment facilities. Effluents were monitored to verify wastewater discharge compliance with USEPA limitations (NPDES permit, Fort Drum), and operational characteristics were observed to form a basis for predicting full-scale operation and maintenance requirements. Data pertaining to loading rates, depths and characteristics of filter media, waste removal efficiency, and other pertinent information related to the performance and design of such a system were to be provided to the New York District after the completion of pilot-scale studies.

2 DESCRIPTION OF PILOT STUDIES

Physical Location and Layout

The site recommended for the centralized wash facility (Figure 1) was chosen because it is located along a road on which most vehicles return to cantonment areas after completing field maneuvers. The pilot plant site was in the same area recommended for centralized wash facilities. The area now has four wastewater-generating washracks and an abundance of natural sand deposits.

Figures 2 and 3 illustrate the physical layout of the pilot studies. The 431-ft (131-m) ditch constructed to channel wastewater generated from washracks No. 2090 and 2091 to the study area was lined with white nylon-reinforced plastic. This material was also used as a liner in the holding pond and the two weir boxes. Exterior plywood sheets were used to construct the sand filters and weir boxes, and precut steel channels were bolted together to assemble the framework for the filter walls. Sheets of tongue and groove exterior plywood, 3/4 in. (1.9 cm) thick, were bolted to the frame. The field dimensions for each of the two filters were 9 ft, 10 in. (3 m) wide; 9 ft, 10 in. (3 m) long; and 8 ft (2.4 m) high. Construction grade, 2-in. by 4-in. (5 x 10 cm) lumber was cut and assembled to form the framework for the weir boxes, which had interior dimensions of 6 ft (1.8 m) wide, 6 ft (1.8 m) long, and 4 ft (1.2 m) deep. A hole was cut in one wall of each box and a 22 1/2 degree metal weir was mounted in it to allow flow measurement.

The plywood filter walls were treated with multiple layers of waterproofing epoxy prior to placing the underdrains and media. Native sand was placed and shaped as a support for a polyethylene bottom cover. Perforated polyvinyl chloride pipe of 4-in. (10-cm) diameter was placed in two parallel sections at the bottom of each filter. The underdrains were located parallel to the filter walls and topped with 1 ft (0.3 m) of graded gravel. These pipes manifolded to a discharge pipe which acted as the effluent collection system for the sand filters. Two depths of sand media, 2 ft (.6 m) and 3.5 ft (1.05 m), with an effective size (D_{10})* of 0.23 mm were placed in the two filters.

In addition to the large sand filters, four 1-ft (.3-m) diameter filter columns were used to evaluate natural sand deposits (effective size (D_{10}) of 0.21 mm) and to supplement data obtained on the media used in the large filters. Two depths of each sand type corresponding

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* Sieve nominal diameter at which 10 percent of the sand is retained in a sieve analysis procedure.

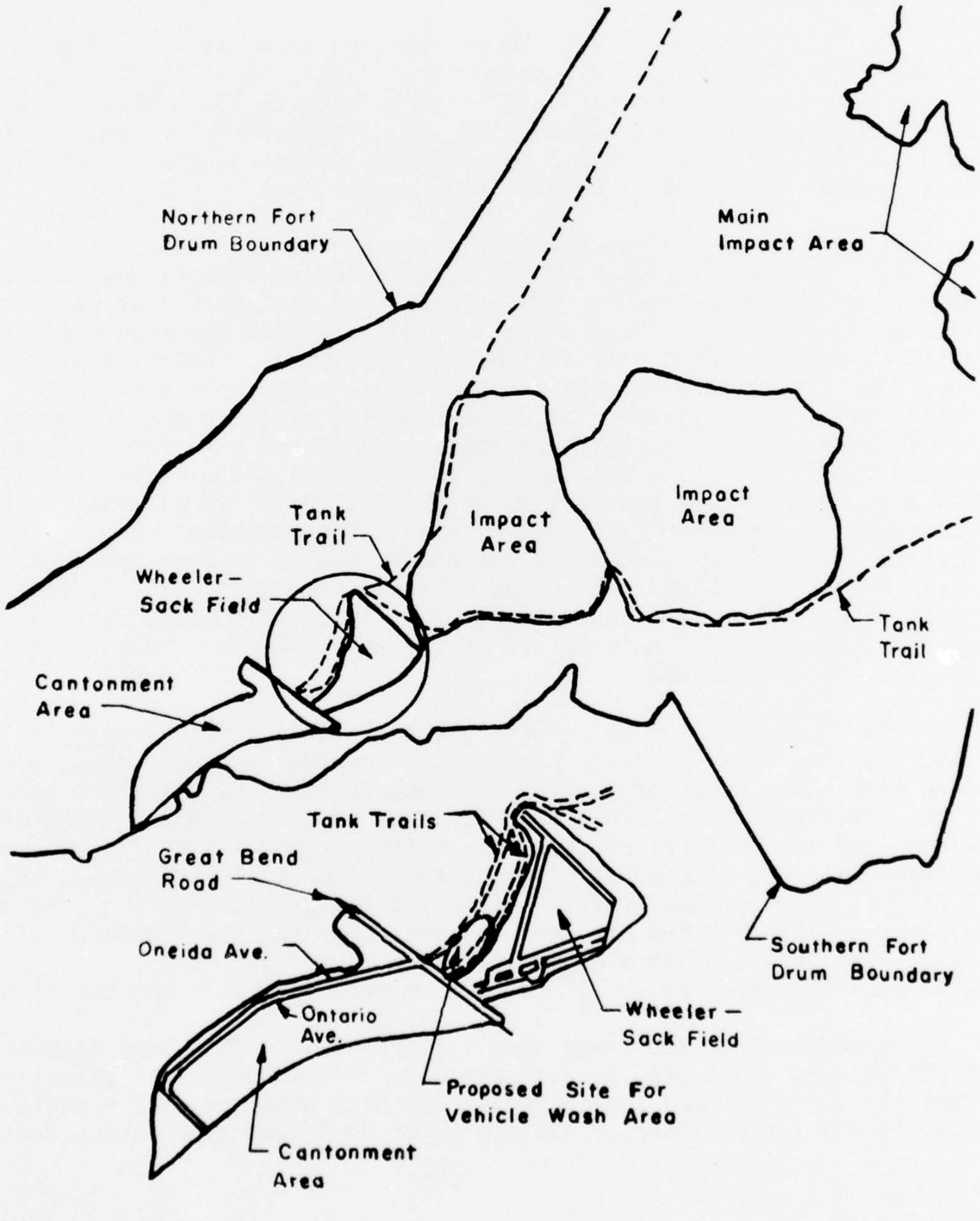


Figure 1. Partial site map, Fort Drum, NY.

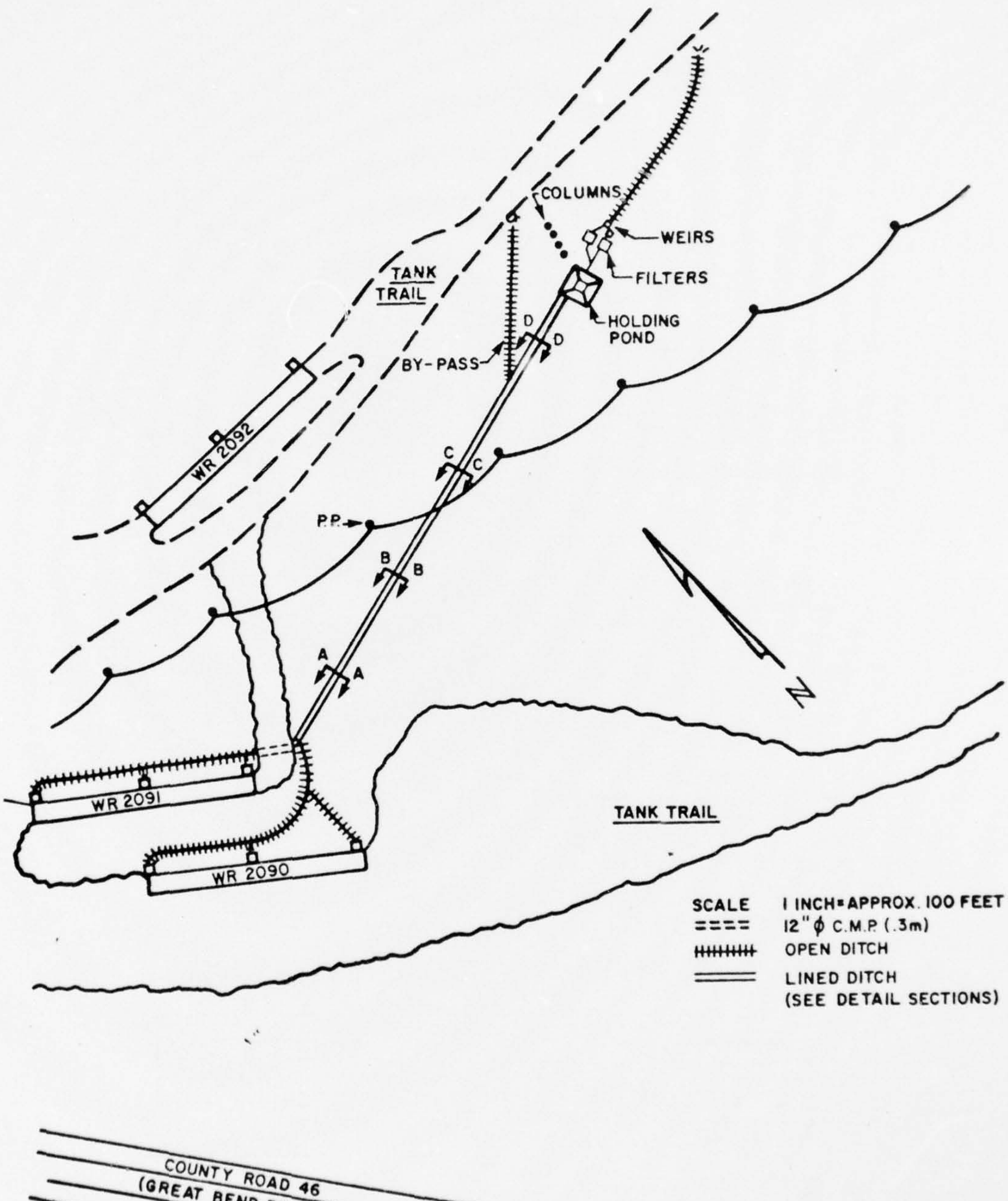


Figure 2. General site layout--pilot plant operation.

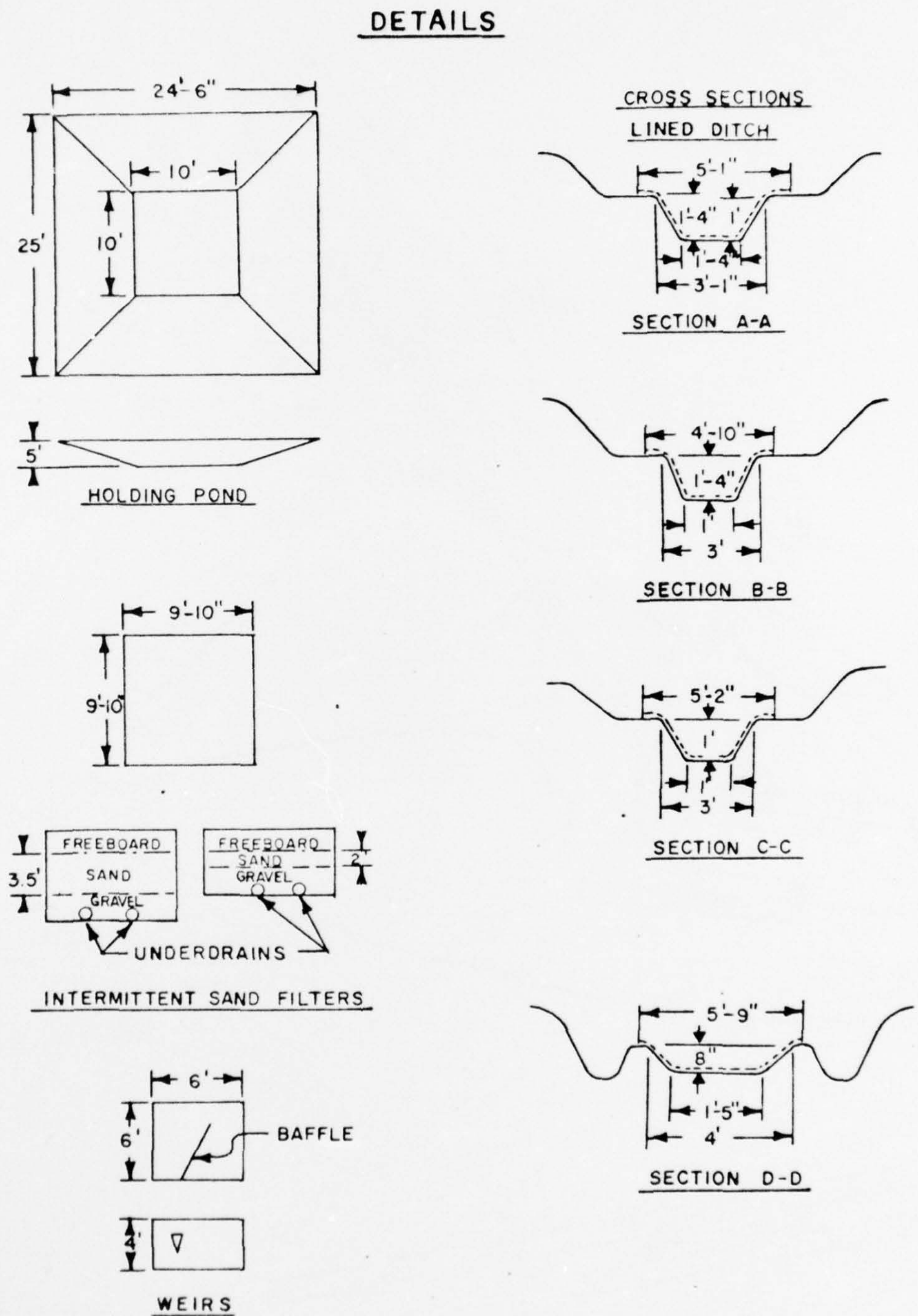


Figure 3. Details--general site layout. (Metric conversion factors: 1 ft = .3 m; 1 in. = 2.54 cm)

to the depths within the large filters were used in the column filters. The columns were constructed of galvanized sheet metal fashioned into 12-in. (.3-m) diameter cylinders, 6 ft (1.8 m) in height, having soldered joints with a valved discharge outlet at the bottom. The four columns were placed adjacent to the large sand filters (see Figure 4). Appendix C provides the sieve analyses of the quarry and native sands.

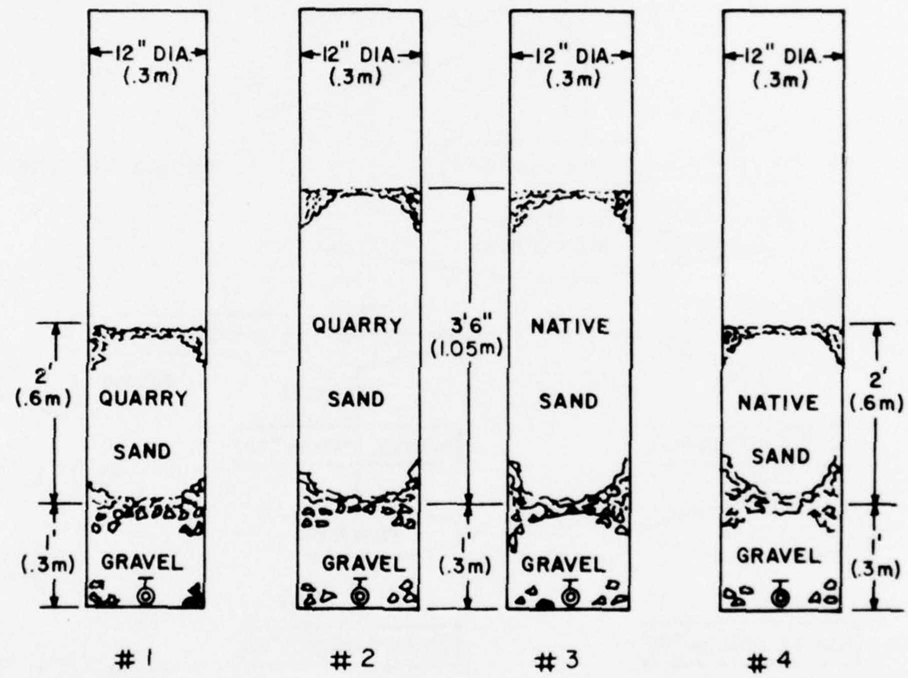


Figure 4. Cross section of filter columns.

Operation Procedures

The pilot plant operation procedures were varied to determine desirable surface loading rates which were consistent with a good-quality effluent. Figure 5 and Table 1 illustrate sample points and flow pattern for the pilot study. Discharges from washracks were collected and conveyed to a sedimentation basin, where the detention time was a minimum of 2 hours. The valving scheme allowed settled wastewater to be applied directly to the two large filters. Loading was measured by determining filter effluent flow using a 22 1/2 degree "V"-notch weir in a stilling basin, and by monitoring water level in the sedimentation basin and filter boxes. The column filters were loaded manually using graduated containers. Filter loading rates

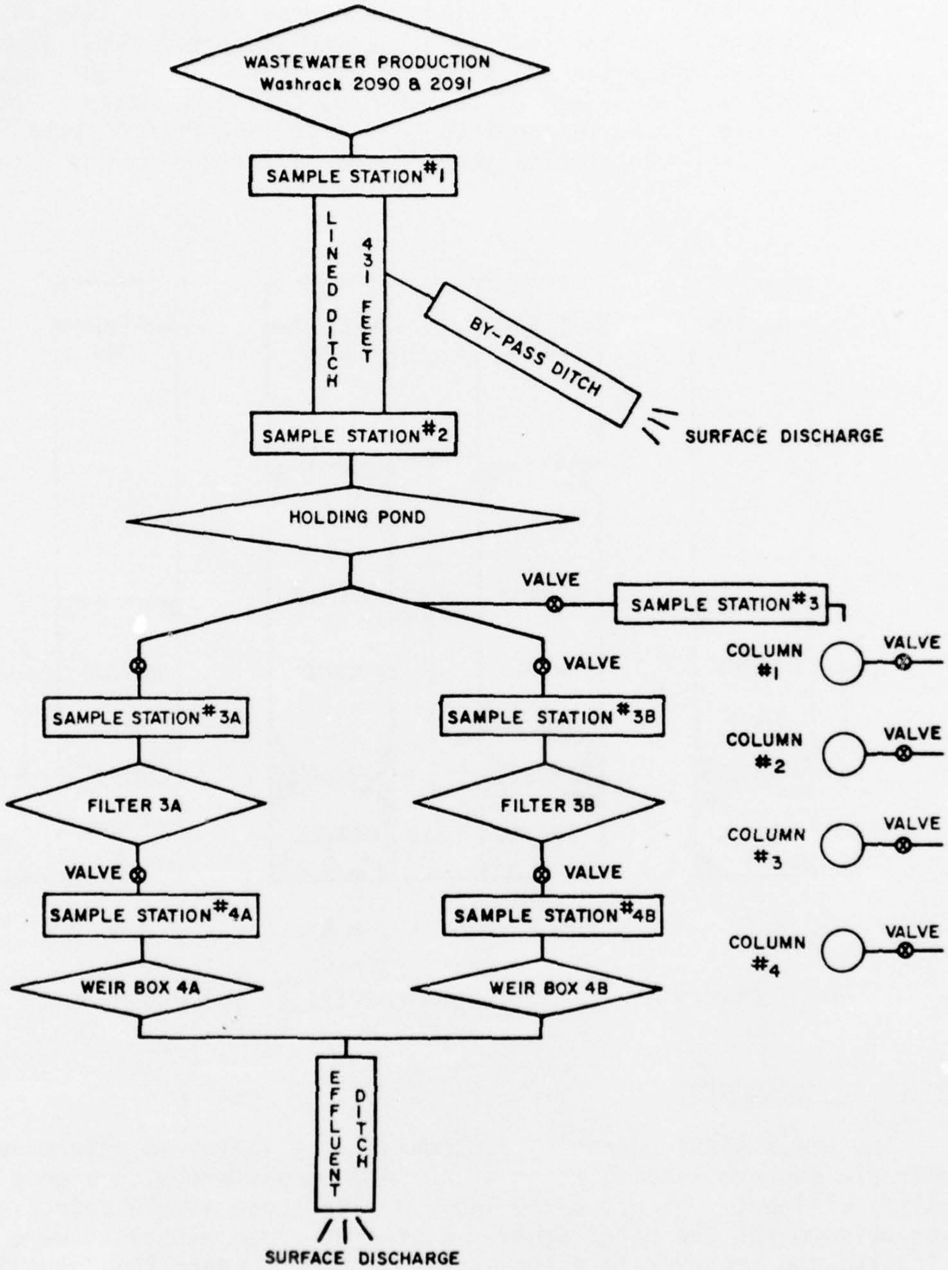


Figure 5. Schematic of pilot studies.

Table 1

Key: Pilot Plant Scheme

Designation:	Description:
Washrack 2090	Concrete slab with 17 3/4 in. (1.9 cm) hose bibs
Washrack 2091	Concrete slab with 17 3/4 in. (1.9 cm) hose bibs
Sample Station #1	Sample point located 3 ft (.9 m) from lined ditch beginning.
Lined Ditch	431-ft (131 m) ditch lined with nylon reinforced polyethylene sheeting, 6 ft (1.8 m) wide.
By-Pass Ditch	Unlined ditch used as a bypass for excess wastewater.
Sample Station #2	Sample point located at effluent of the lined ditch (or influent to holding pond).
Holding Pond	Nylon-reinforced polyethylene lined pond with a 3-in. (7.6-cm) diameter effluent PVC pipe located 2 ft (.6 m) higher than the bottom.
Sample Station #3	Valved outlet pipe located in the holding pond effluent line to provide settled wastewater for Columns 1-4.
Sample Station #3A	Valved 3-in. (7.6-cm) influent to Filter A.
Sample Station #3B	Valved 3-in. (7.6-cm) influent to Filter B.
Filter A	3.5 ft (1.05 m) deep sand filter.
Filter B	2.0 ft (.6 m) deep sand filter.
Sample Station #4A	Valved 2-in. (5-cm) effluent from Filter A.
Sample Station #4B	Valved 2-in. (5-cm) effluent from Filter B.
Weir Box A and Weir Box B	A stilling basin with a Stevens level recorder and a 22 1/2 degree V-notch weir for effluent measurement.

Table 1 (cont.)

Designation:	Description
Effluent Ditch	Unlined ditch used to discharge all effluent waters to surface drainage.
Column #1	12-in. (.3-m) diameter column with 2 ft (.6 m) of purchased sand (same type and depth as Filter B).
Column #2	12-in. (.3-m) diameter column with 3.5 ft (1.05 m) of purchased sand (same type and depth as Filter A).
Column #3	12-in. (.3-m) diameter column with 3.5 ft (1.05 m) of quarry sand (sand used as found at site).
Column #4	12-in. (.3-m) diameter column with 2.0 ft (.6 m) of quarry sand (sand used as found at site).

ranged from 3 to 6 in. (7.6 to 15.2 cm) of wastewater per application with up to three applications per day.

Laboratory and Field-Measurement Tests and Techniques

CERL personnel tested the washrack wastewater in a chemistry laboratory at Jefferson Community College, Watertown, NY. Sample storage apparatus, laboratory equipment, and chemicals for analytical procedures were supplied by CERL. Analytical methods used were:

1. pH: A Beckman Electromate pH Meter, model number 100900, with a combination electrode was used for pH determinations. The manufacturer's instructions for pH measurement were followed. The instrument was standardized with a buffer solution having a pH approaching that of the sample. Testing was generally performed as soon as the sample arrived at the laboratory.

2. Chemical oxygen demand (COD): COD Method 220, *Standard Methods for the Examination of Water and Wastewater*, 13th ed., 1971, was used for COD analysis. Samples were acidified with sulfuric acid and stored at 4°C for preservation. Two sets each of filtered and unfiltered samples were refluxed to determine the amount of oxidizable matter which adheres to inorganic solids. Samples were generally refluxed within 24 hours after being collected.

3. Residue: Methods 224C and 224D of *Standard Methods* were employed for suspended solid (SS) and volatile suspended solid (VSS) determination. Membrane filters were used to analyze SS alone, but when both SS and VSS were determined, Gooch crucibles and glass fiber filters were used. The two methods were compared by splitting several samples and analyzing them with both a membrane filter and Gooch crucible. Samples were stored at 4°C; some were acidified when the sample was also used to determine COD.

4. Grease and oil: The Soxhlet Extraction Method, pp 226-228 of the USEPA's *Manual of Methods for Chemical Analysis of Water and Wastes* was used. Samples were collected in wide-mouthed Mason jars, preserved with sulfuric acid, and stored at 4°C. Samples were generally extracted within 24 hours of collection, and analysis was completed within 36 hours.

5. Turbidity: A Hach Turbidimeter, Model Number 2100A, was used to measure turbidity. Manufacturer's instructions for use were followed. Samples were either analyzed immediately after arriving at the laboratory, or stored at 4°C for later analysis. (Some samples were acidified if also used for COD determinations.)

3 RESULTS AND DISCUSSION

Results

Water used for vehicle washing was monitored at Fort Drum during the 1976 training season. Water meters were installed at most washracks to aid in measuring washrack wastewater flow, as required by the current NPDES permit. Figure 6 and Table 2 summarize water usage data. Washracks were used 1 to 3 days per week--normally within a 4-day period beginning Wednesday and ending Saturday. Vehicle washing activities usually coincided with the termination of 2-week training periods.

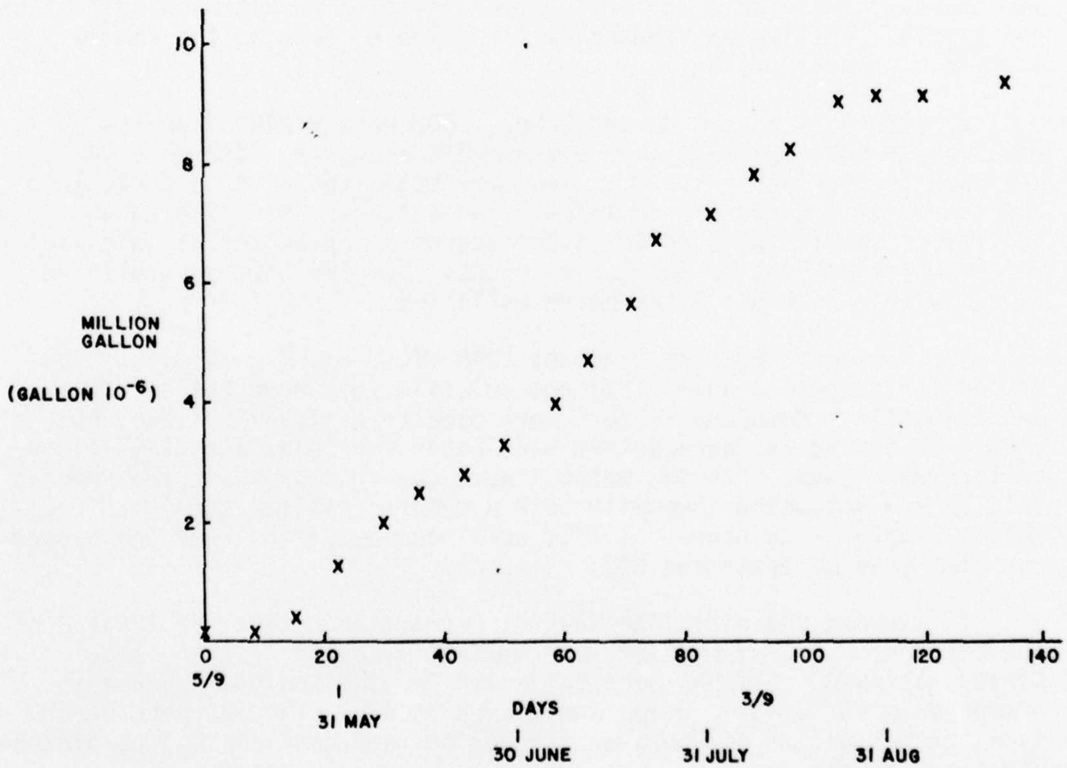


Figure 6. Cumulative water usage vs. time, Fort Drum, NY, summer 1976.

As shown in Figure 2, pilot plant operations received wastewater from two washracks--No. 2091 and No. 2092. These washracks recorded the highest water usage during the 1976 training season--2.5 million

Table 2

Washrack Water Usage - Fort Drum, NY, 1976

Meter Reading Date and Day of the Week	# of Days	# of Likely Wash Days	(Volumes in Gallons x 10^{-3}) Washrack(s); number of hose bibs is indicated parenthetically: 2091 2092 (34)	2093 (20)	2090 (17)	1693 1694 (8)	1590 (4)	1591 1592 (7)	1593 1594 (7)	1690 (4)	1691 (4)	Σ
9 May (Su)	-	-	0	0	1	12	22.2	3.7		0	3.9	43
18 May (Tu)	9	3	0	10	13	11.7	8.4	5.7		2.6	2	53
24 May (M)	6	3	60	30	78	71.5	34.3	26.8		13	25.8	339
31 May (M)	7	3	210	230	127	96.8	25.4	87.1	Metered	18.6	27.4	822
8 Jun (Tu)	8	3	160	190	79	61.6	50.5	48.5		32.8	20.8	643
14 Jun (Tu)	6	3	220	70	116	67	37.8	73.6	after	4.2	21	610
21 Jun (M)	7	3	70	10	53	40.7	29.6	54		17.4	16.3	291
28 Jun (M)	7	3	170	100	110	49.9	34.7	36.9	28 June	16.1	19.9	538
6 Jul (Tu)	8	3	90	130	48	93.9	72.5	68.1	85.3	34.1	38	660
12 Jul (M)	6	3	120	170	63	70.7	58.9	58.9	73.7	36.1	46.7	698
19 Jul (M)	7	3	240	190	45	108.9	127.5	70.8	146.8	80.1	11.1	1020
23 Jul (F)	4	2	290	140	79	63.2	126	76.9	121	60.7	6.2	963
2 Aug (M)	10	4	140	50	81	29.9	34.6	16.7	104.2	4	5.3	466
9 Aug (M)	7	3	170	130	99	59.4	40.5	28.9	128	15.7	18.1	690
15 Aug (Su)	6	3	50	100	35	52	38.1	71.6	64.6	15.7	19.6	447
23 Aug (M)	8	3	140	160	64	78.4	65.6	75	84.8	37.8	28.6	734
30 Aug (M)	7	3	10	0	4	28.3	3.9	1	-	0.7	0.2	48
6 Sep (M)	7	3	30	-	-	-	-	-	-	-	-	30
20 Sep (M)	14	6	270	-	-	-	-	-	-	-	-	270
15 Oct (F)	25	12	20	15	-	-	-	-	-	-	-	35
31 Oct (M)	16	7	50	25	-	-	-	-	-	-	-	75
TOTAL DURING SEASON			2510	1750	1095	996	811	804	808	390	311	9474

gal (9.46 million ℓ). During the CERL study, the two washracks were used primarily for cleaning armored tracked vehicles. The 1975 study[2] concluded that wastewater from tracked vehicle washracks contains the highest concentrations of suspended solids, grease, and oil.

Figures 7 through 10 present the average and the range of parameter values for sampling points used to monitor the pilot plant operation. These figures summarize data for the total operating period of the large filters. Figures 11 through 18 summarize the suspended solids and turbidity data collected from the four column filters; these data are also for the *total period* of operation. It should be noted that average values for parameters monitored exceed the USEPA's recommended limitations at the filter effluent. For example, the average suspended solids concentrations for water from both large filters were 60 and 90 mg/ℓ (Figure 7). The USEPA 30-day average effluent limitation is 30 mg/ℓ (see Table 10 of the USEPA regulations in Appendix A).

Fewer data than expected were accumulated for the large gilters and column figures because of the abbreviated study period; however, substantial data were obtained from the column filters operation. Figures 11 through 18 depict filter influent and effluent characteristics for individual wastewater applications during the study period. Each column filter shows the anticipated improvement in performance with time. This continued improvement with use would shortly provide a degree of treatment which exceeds NPDES requirements.

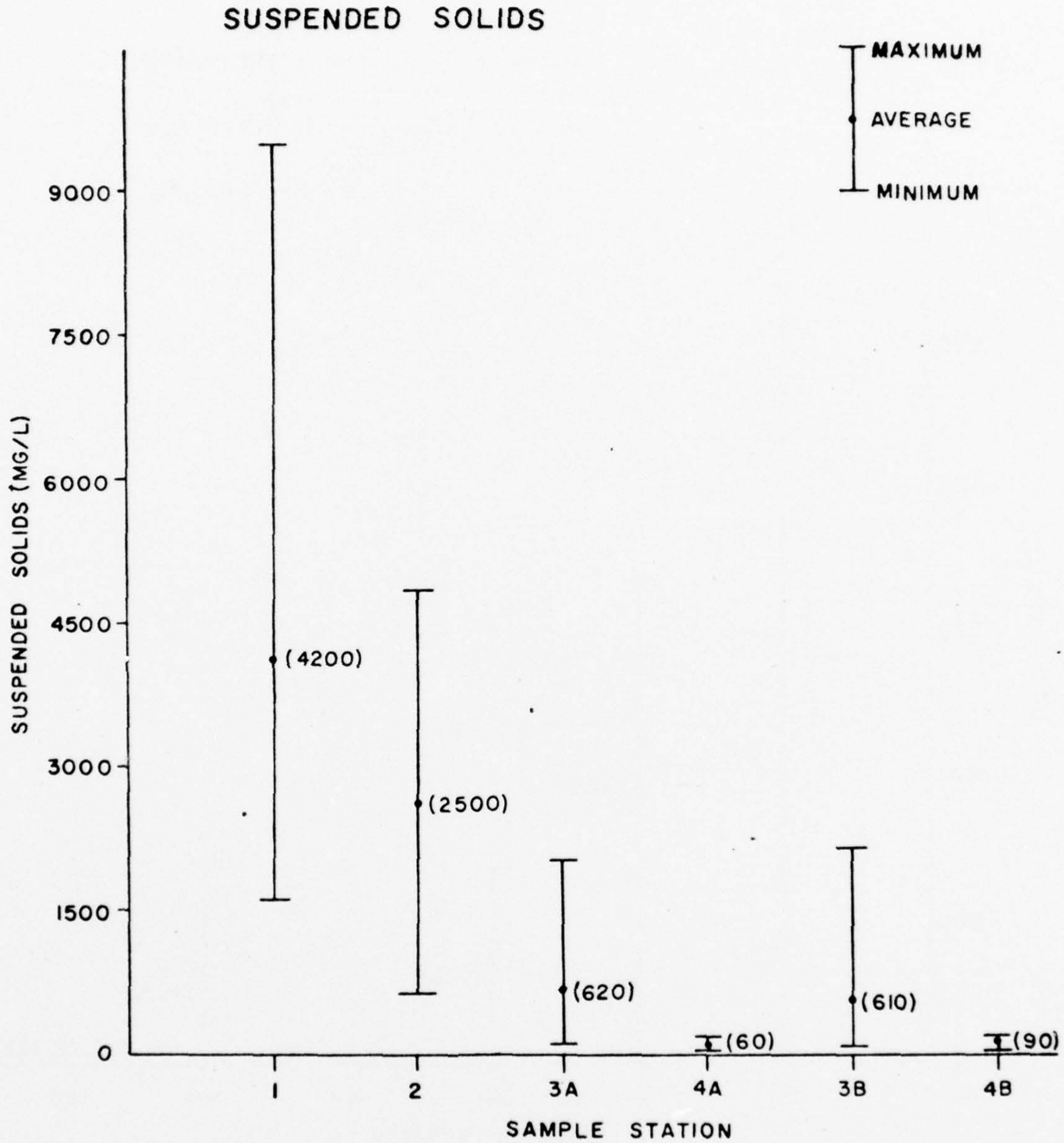
Organic content of wastewaters, as monitored by the grease and oil and COD analyses, was found to be low during pilot plant study. In the absence of significant soluble organics, the performance of the filter in treating wastewaters with highly dissolved organics could be evaluated. COD as shown in Figure 8 indicates relative ranges of organic content found at various sample points in the pilot plant. Oil and grease concentrations greater than those reflected by the data in Figure 10 were observed during the study at Fort Drum. These high concentrations were observed on several occasions and were determined to be the result of fuel or oil dumps at the washracks.

Discussion

Filter Performance

As was anticipated in the study planning, filter performance improved with use; effluent from all filters improved with succeeding applications of wastewater due to (1) a gradual reduction in the amount of

[2] *Vehicle Washing Operations and Wastewater Discharges, Fort Drum, NY, Findings and Recommendations*, Technical Report E-80/ADA026173, (CERL, June 1976).



STATION 1 → WASTEWATER DIRECTLY FROM WASHRACK(S)
STATION 2 → INFLUENT TO HOLDING POND
STATION 3A → FILTER INFLUENT
STATION 4A → EFFLUENT FROM FILTER 3A
STATION 3B → FILTER INFLUENT
STATION 4B → EFFLUENT FROM FILTER 3B

Figure 7. Summary--suspended solids data.

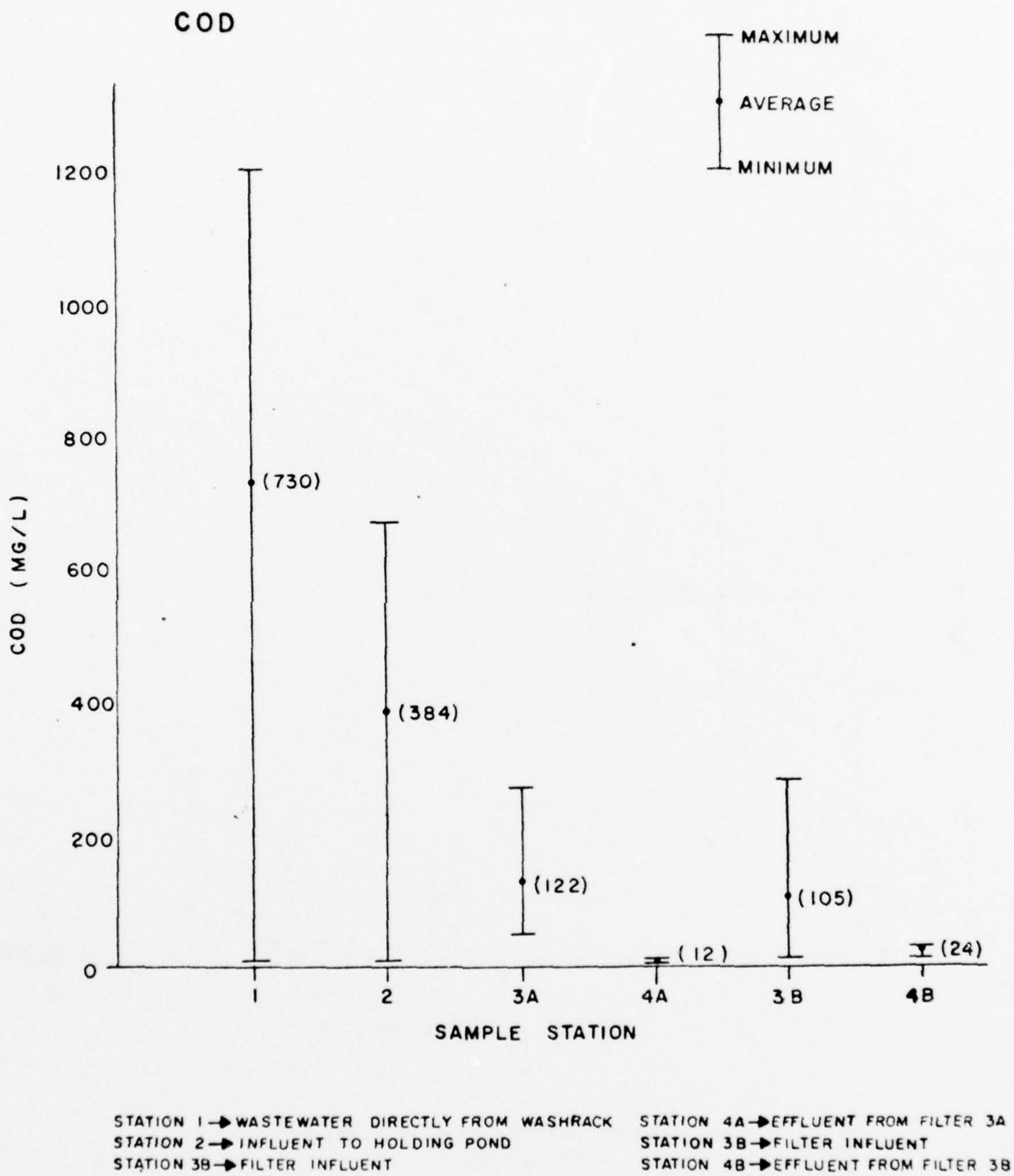


Figure 8. Summary--chemical oxygen demand (COD) data.

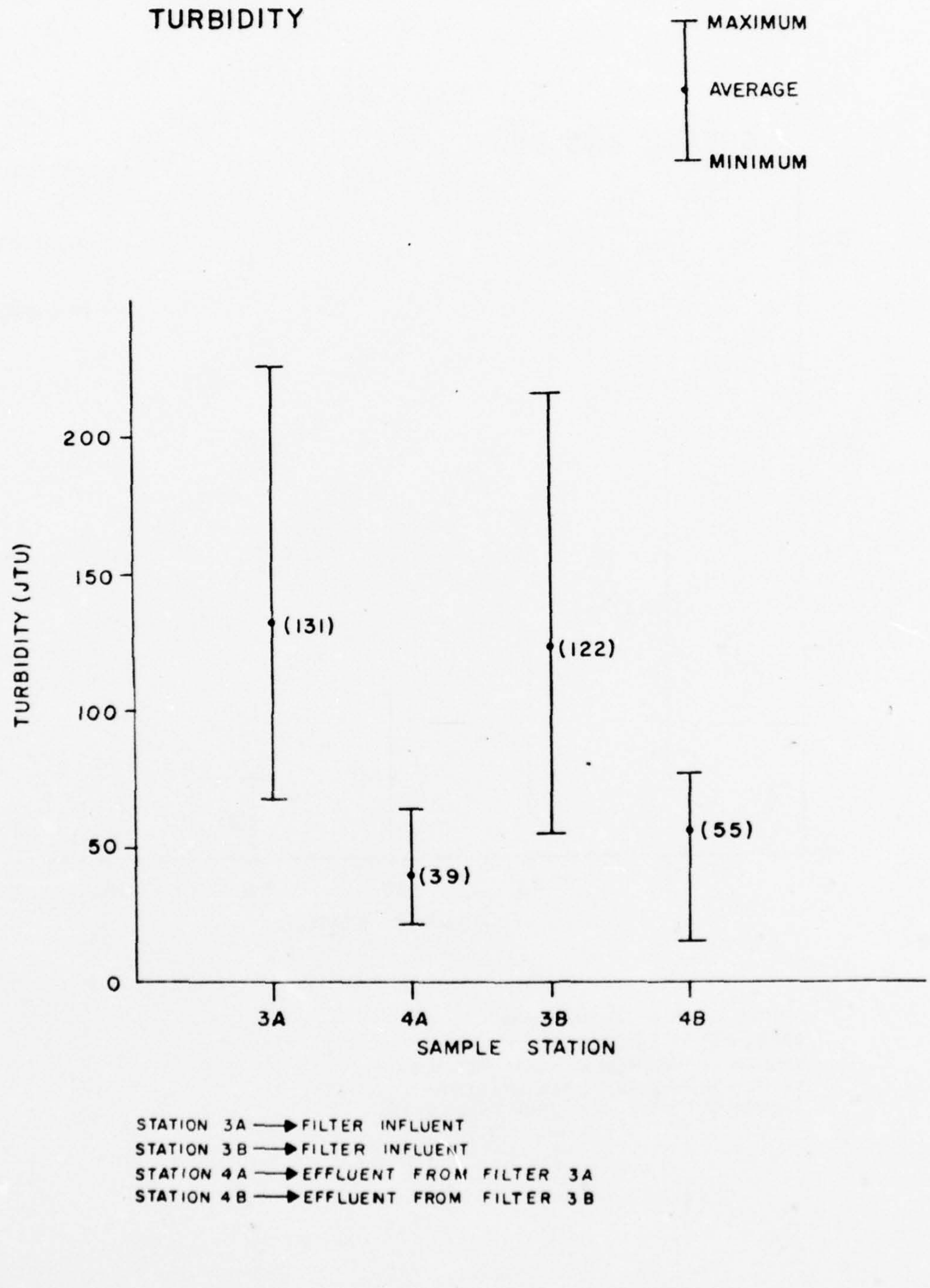


Figure 9. Summary--turbidity data.

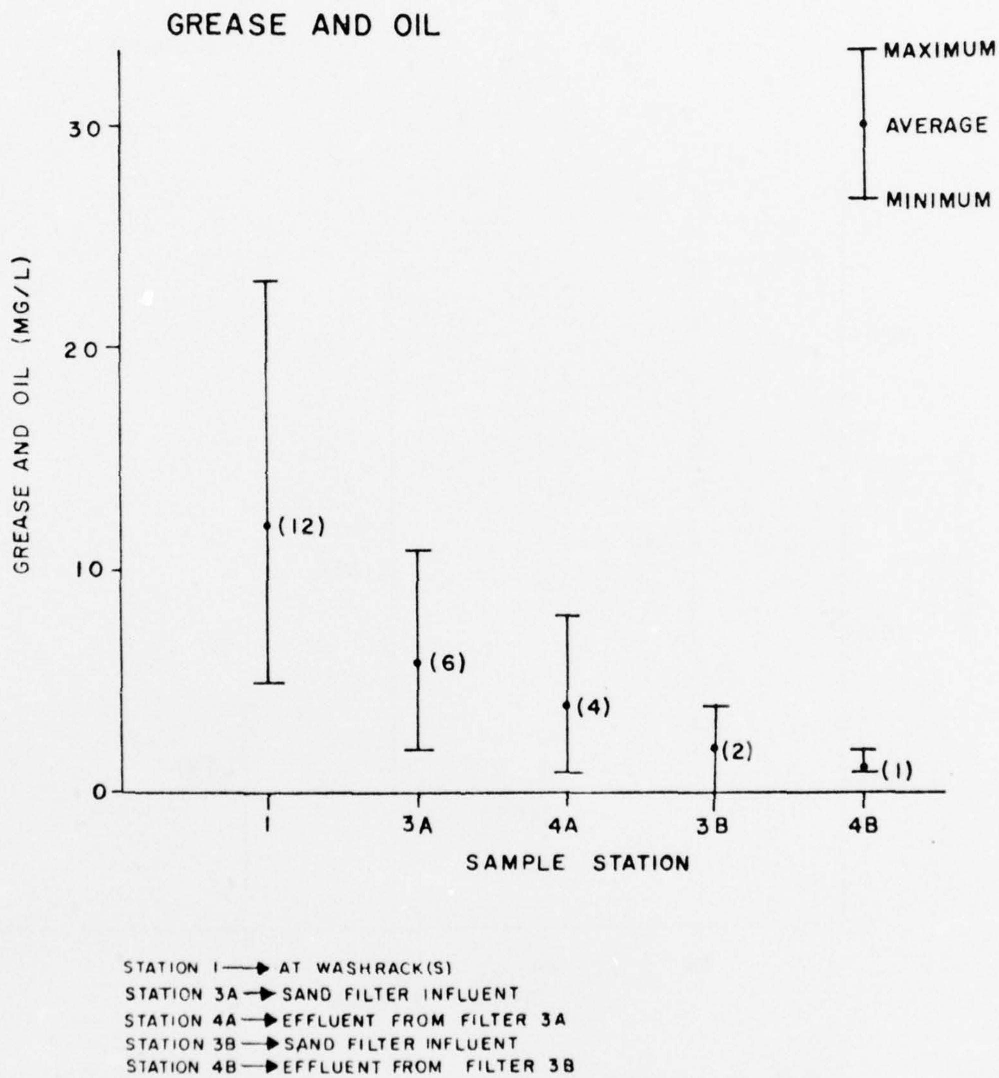


Figure 10. Summary--grease and oil data.

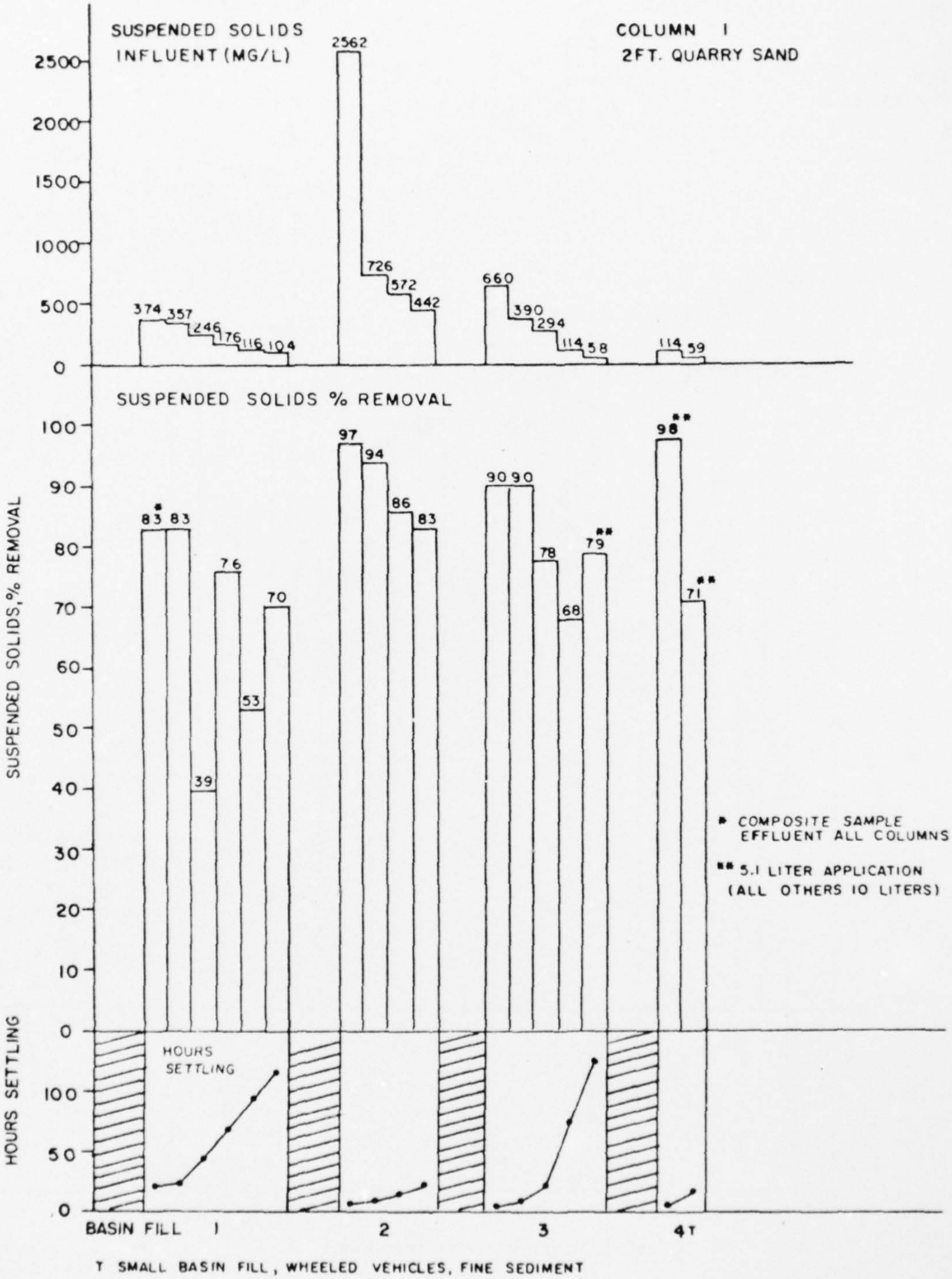


Figure 11. Summary--suspended solids, percent removal, Column 1.

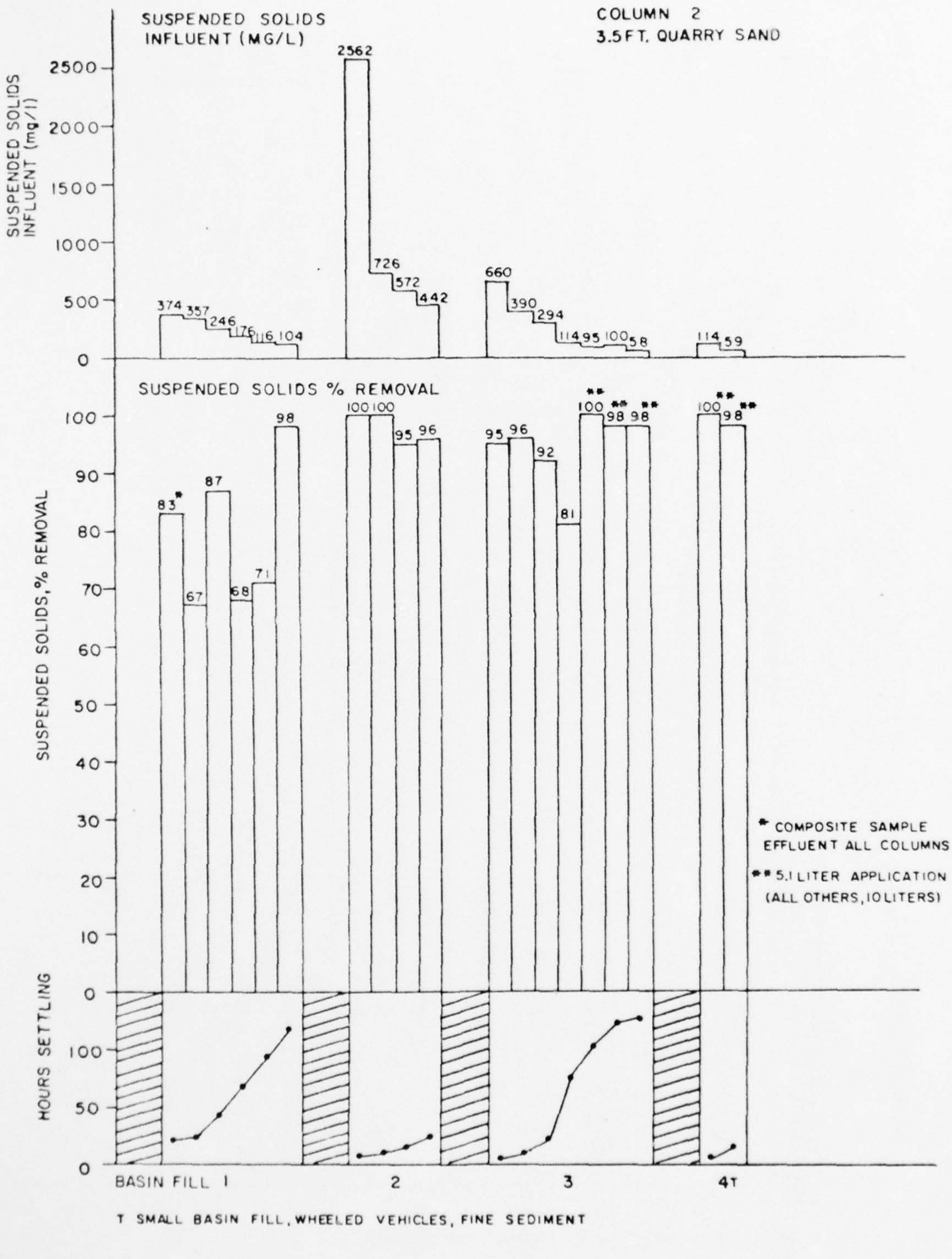


Figure 12. Summary--suspended solids, percent removal, Column 2.

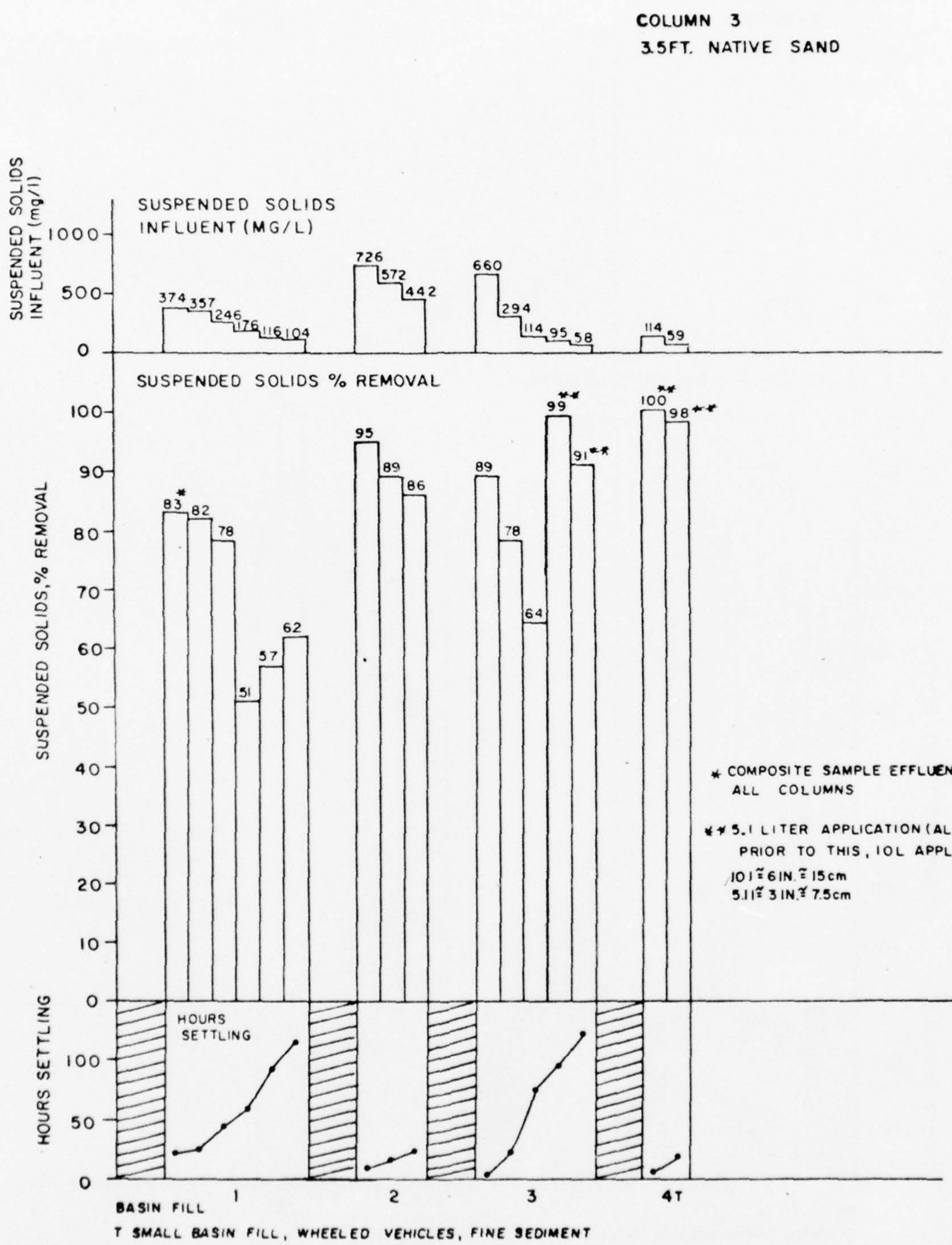


Figure 13. Summary--suspended solids, percent removal, Column 3.

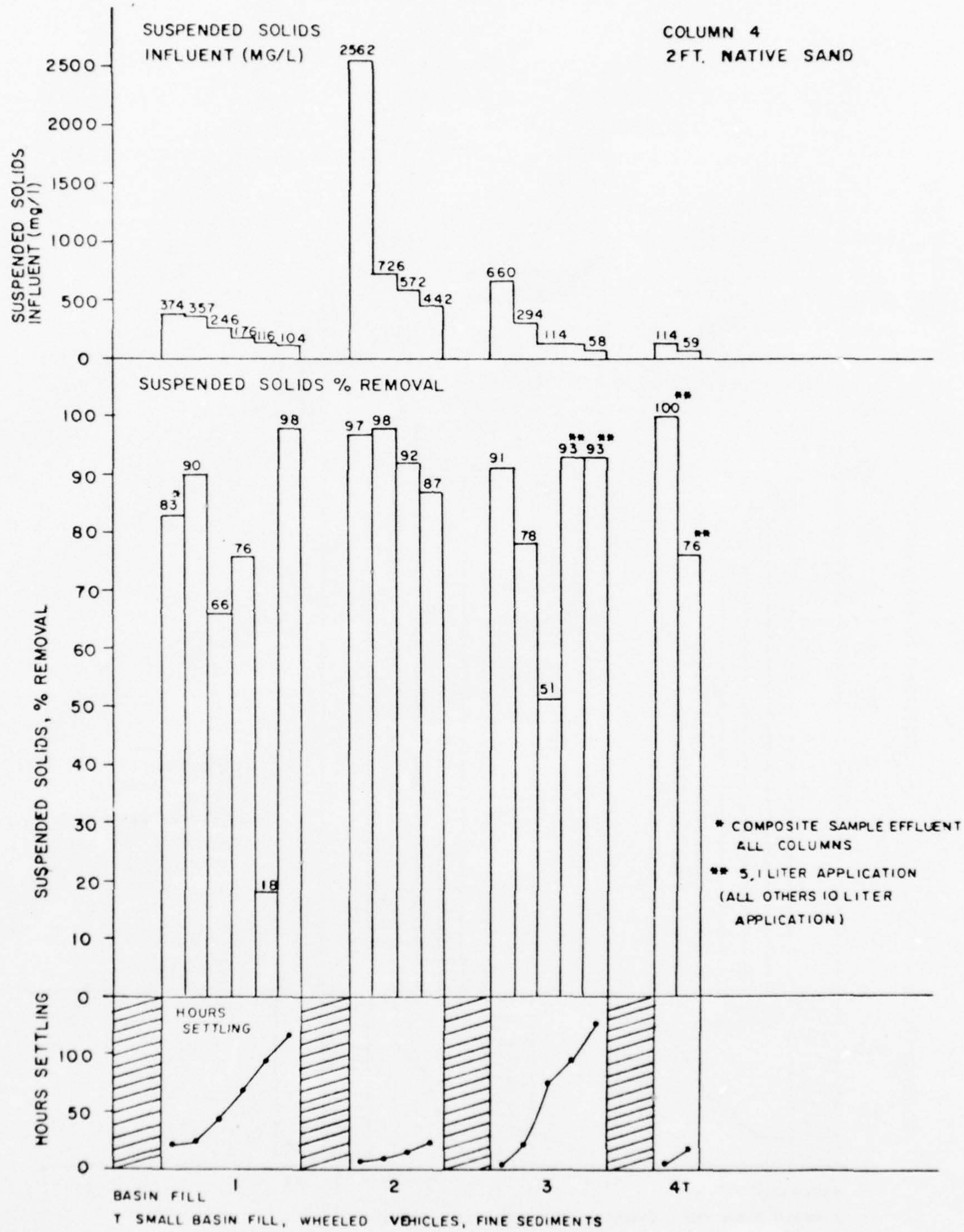


Figure 14. Summary--suspended solids, percent removal, Column 4.

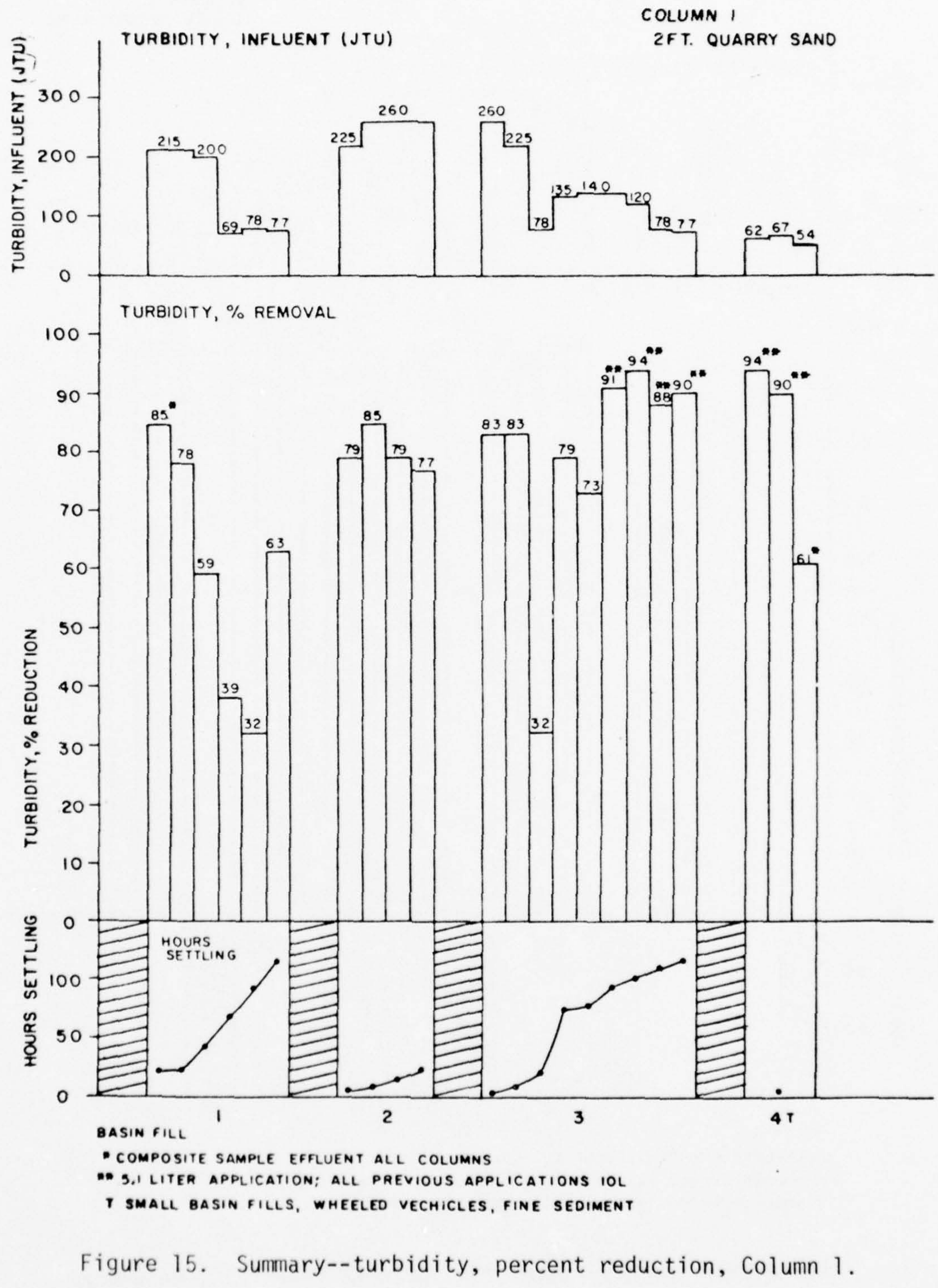


Figure 15. Summary--turbidity, percent reduction, Column 1.

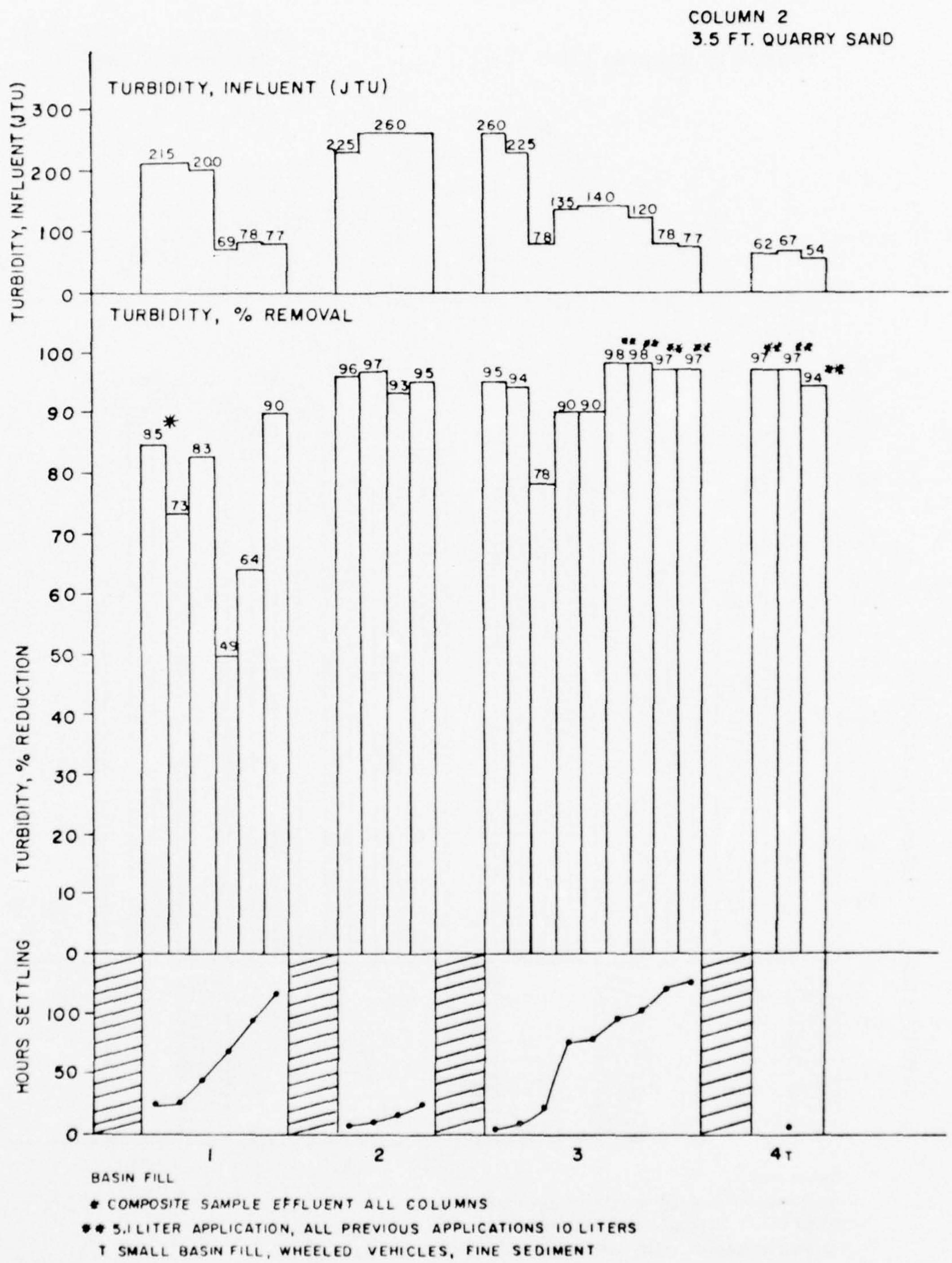


Figure 16. Summary--turbidity, percent reduction, Column 2.

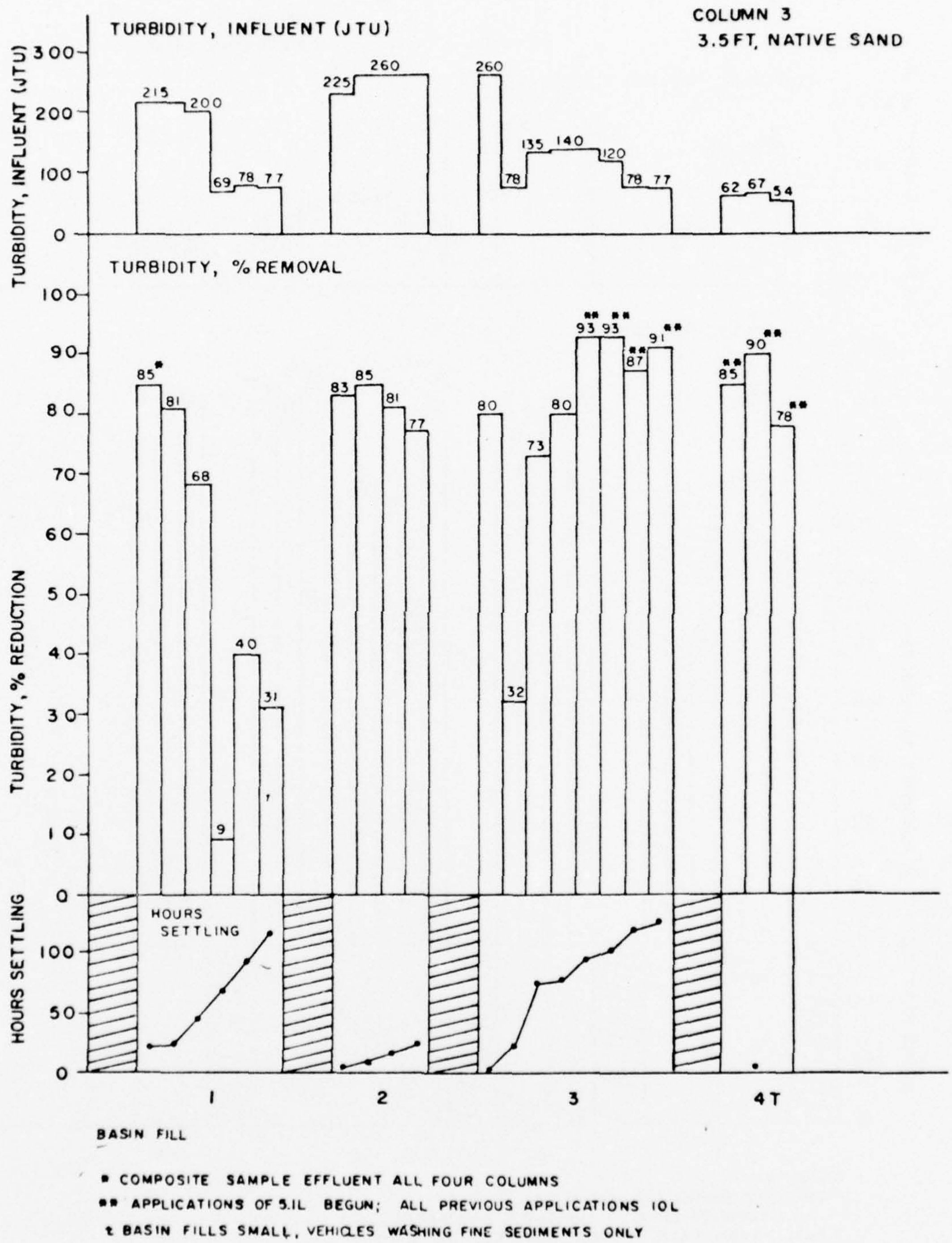


Figure 17. Summary--turbidity, percent reduction, Column 3.

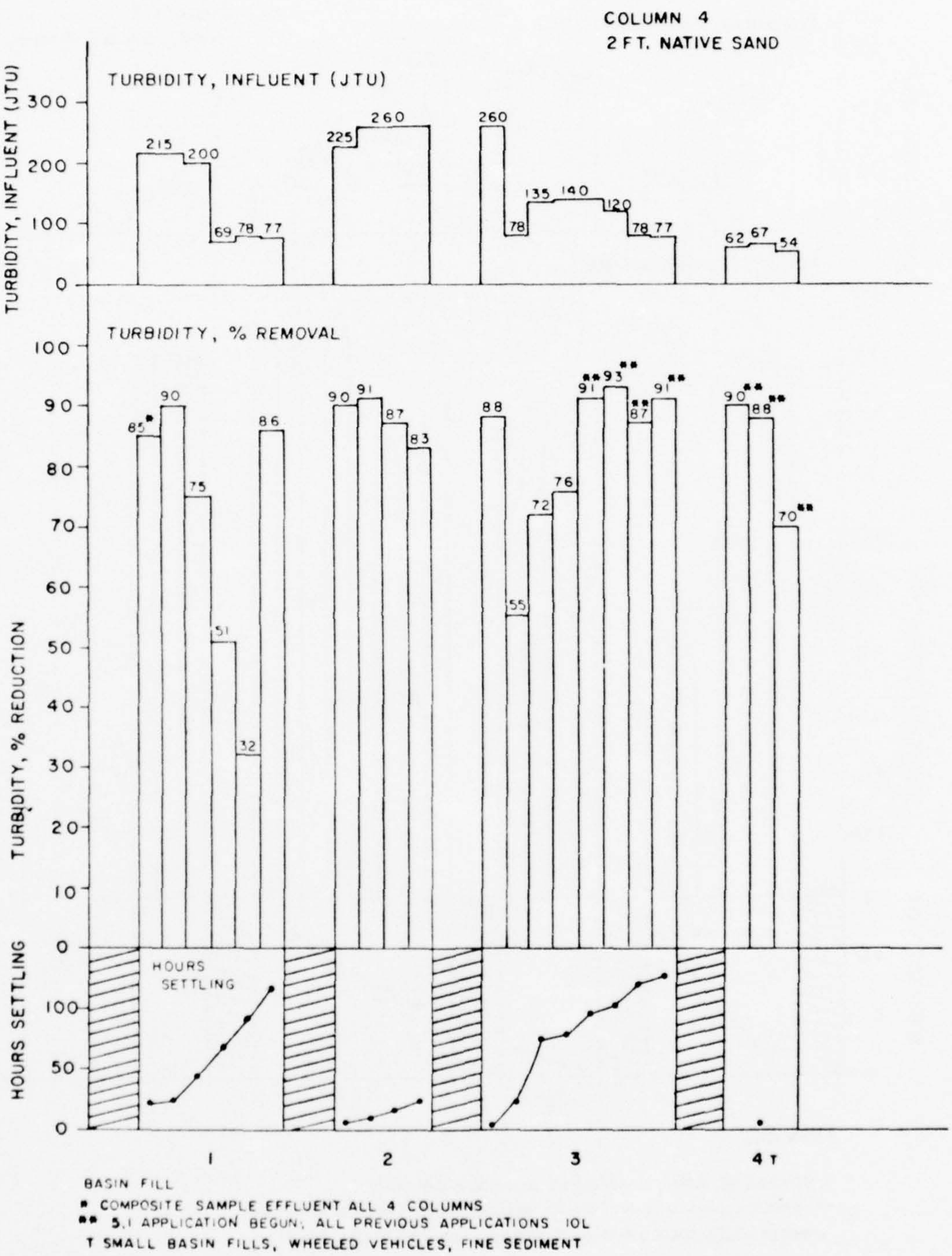


Figure 18. Summary--turbidity, percent reduction, Column 4.

fine material washed from filter media, and (2) the development of a thin surface coating on filter beds. In addition, filter performance in terms of effluent quality approached what had been anticipated by the end of the study period. On the basis of suspended solids removals at the two application rates used with the column filters--5.1 liter (equivalent to 3 in. or 7.5 cm) and 10 liter (equivalent to 6 in. or 15 cm)--Figures 11 through 18 indicate better performance at the lower hydraulic loadings. The filter columns having 2 ft (.6 m) of media generally exhibited lower suspended solids and turbidity reductions than those found in the deeper (3.5-ft [1.05-m]) filter columns. The number of applications of wastewater to filter columns varied from one to three. Performance of column filters was good with up to three applications per day (Figures 11 through 18).

The suspended solids concentrations in column filter influents varied substantially, reflecting the detention time in the sedimentation basin and the type and degree of soiling of vehicles washed. No attempt was made to apply a consistent quality of wastewater to the filters. Figures 11 through 18 summarize influent suspended solids or turbidity, percent removal, and detention time in the sedimentation basin for each filter column. It may be noted that with decreasing suspended solids concentrations in wastewater applied to filters, there is generally an associated decrease in suspended solids removal efficiency. This, together with decreasing solids concentrations, reflects the difficulty of removal (by filtration) of extremely fine material which does not settle in the detention basin. Average suspended solids removal efficiencies for the filter columns were: column No. 1, 79 percent; column No. 2, 91 percent; column No. 3, 81 percent; and column No. 4, 82 percent. These removal efficiencies are somewhat misleading, however. For example, at the conclusion of the study, column filter No. 3, which contained 3.5 ft (1.05 m) of native sand media, had removal efficiencies comparable to those of column filter No. 2. The low overall efficiency reflects the extended "conditioning" required for native sand media. If operation of filters had been continued, the native sand media probably would have been as effective as the purchased quarry media. Thus, if Fort Drum native sand is used as a filter media, its use will require careful monitoring and possibly additional processing.

The sedimentation basin was effective in removing substantial weight percentages of suspended solids, and in preventing floating grease and oil from reaching the filters. During operation of the pilot plant, no effort was made to quantify the floating grease and oil in the sedimentation basin. Observation confirmed the necessity of requiring a means of oil removal in a full-scale facility, since it is essential that substantial amounts of grease and oil not reach the filters and cause "blinding" effects on their surfaces. The oils and greases can act as a binding agent for suspended solids, creating a mat through which water will not readily pass at the heads normally used in intermittent sand filtration.

Sedimentation in the basin generally reduced suspended solids concentration in the washrack wastewater to levels below 1000 mg/ℓ. The basin constructed for the pilot plant study was not designed to provide data for predicting settling characteristics of the suspended matter in washrack wastewater; its primary purpose was to evaluate intermittent sand filtration of "settled" and "skimmed" washrack wastewaters. A cursory examination of suspended solids removals in the sedimentation basin and previous theoretical considerations derived from information from the 1975 survey established the design criteria for the sedimentation basin. It is also anticipated that the extreme variations in wastewater flow rates from washracks will require flow equalization capability (in the form of another basin) to minimize the size and cost of intermittent sand filters. Such an equalization basin will afford further opportunity for suspended solids removal by settling.

Pilot plant studies at Fort Drum provided very limited information about the operation and maintenance requirements of a full-scale treatment facility. The large (10 x 10 ft [3 x 3 m]) filters were accidentally "plugged" by *continuous* application of washrack wastewater containing high concentrations (2000 mg/ℓ) of suspended solids. The filter surfaces had a coating which prevented infiltration of water with 18 in. (.45 m) of head. After removal of wastewater, the top 2 in. (5 cm) of sand and accumulated deposits were removed, and 2 in. (5 cm) of new sand media placed on the filters. The filters were returned to operation and the original filtration rate and removal of suspended solids were restored.

Time-volume of filtrate studies were performed on the column filters at various times during the study to facilitate estimates of the time and/or volume of throughput between filter surface scrapings; Figures 19 through 22 summarize the results. Little or no decrease in filtration rate was observed during the pilot study; approximately 55 to 60 gal (208 to 227 ℓ) per square foot of filter surface area were applied to each column filter. The column filters retained 1.6 to 1.7 lb (.73 to .77 kg) of the 1.8 lb (.82 kg) of suspended solids applied to 2 sq ft (.09 m^2) of filter surface area. Figure 23 depicts cumulative applied, retained, and passed weights of suspended solids for filter column No. 2.

Based on available data, intermittent sand filters would probably not require surface scraping each season; however, a more specific definition of surface maintenance requirements can be obtained only by additional study. Operation and maintenance requirements for intermittent sand filters and sedimentation facilities will generally be minimal in comparison to more conventional wastewater treatment alternatives; however, continuous wastewater application to filters must be avoided, grease and oil skimming devices will need maintenance, and settled solids in the sedimentation basin cannot be allowed to accumulate to the point where they interfere with the function of the

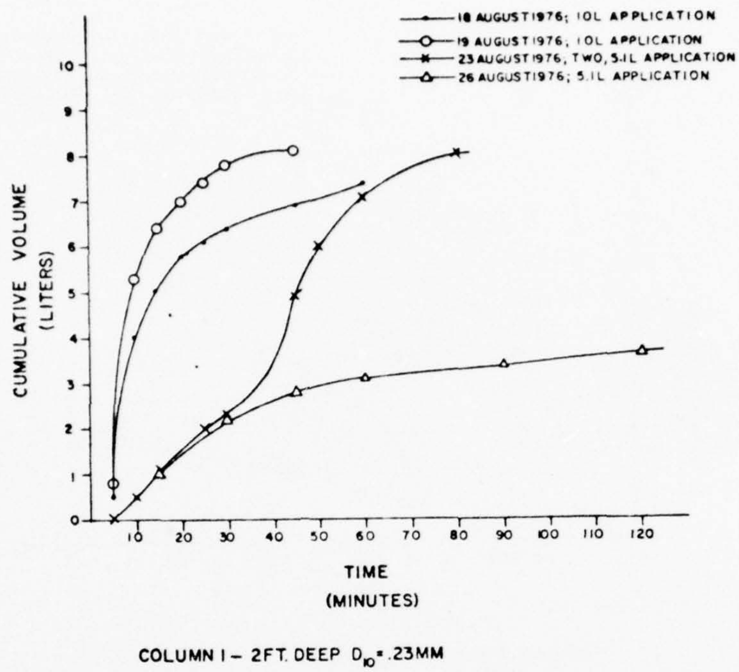


Figure 19. Time-volume--Column 1.

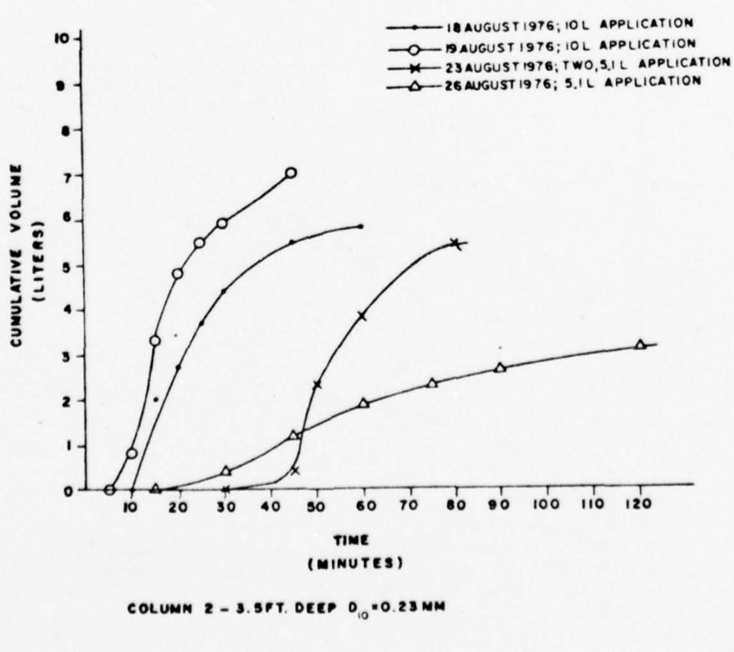


Figure 20. Time-volume--Column 2.

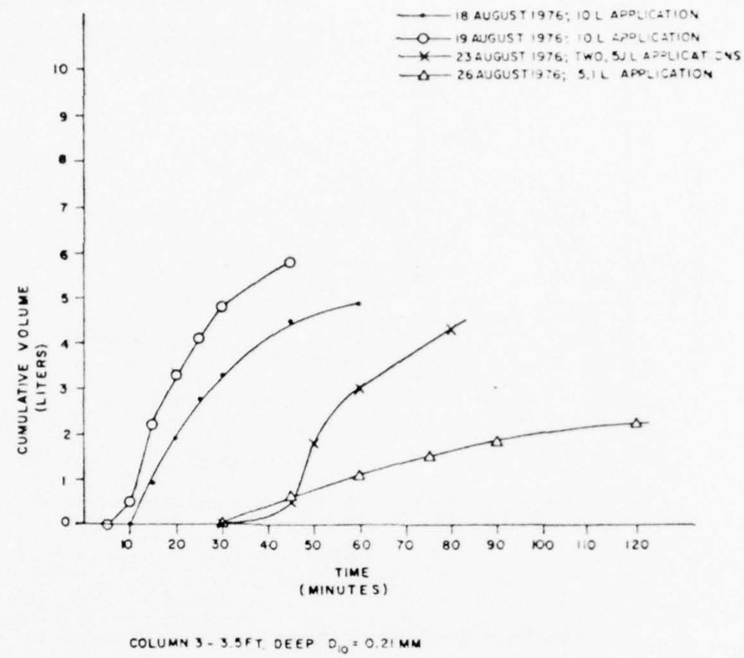


Figure 21. Time-volume--Column 3.

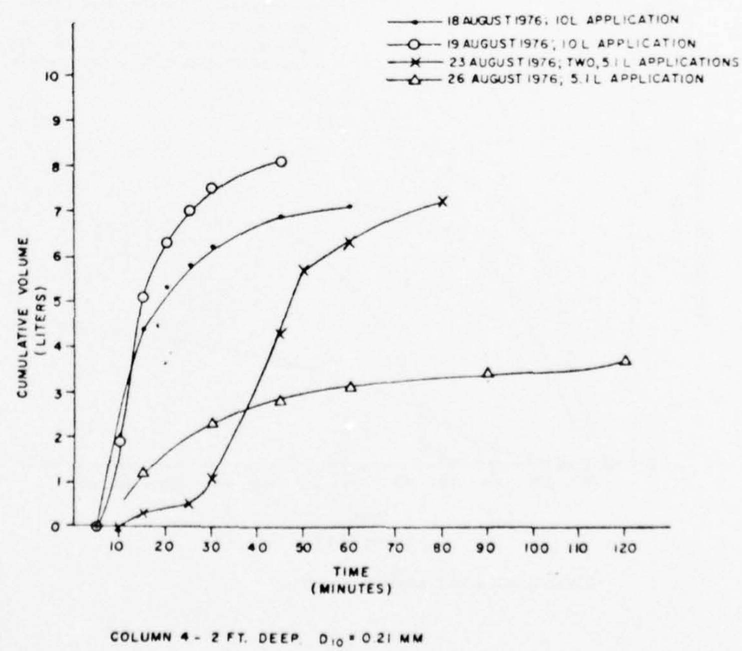


Figure 22. Time-volume--Column 4.

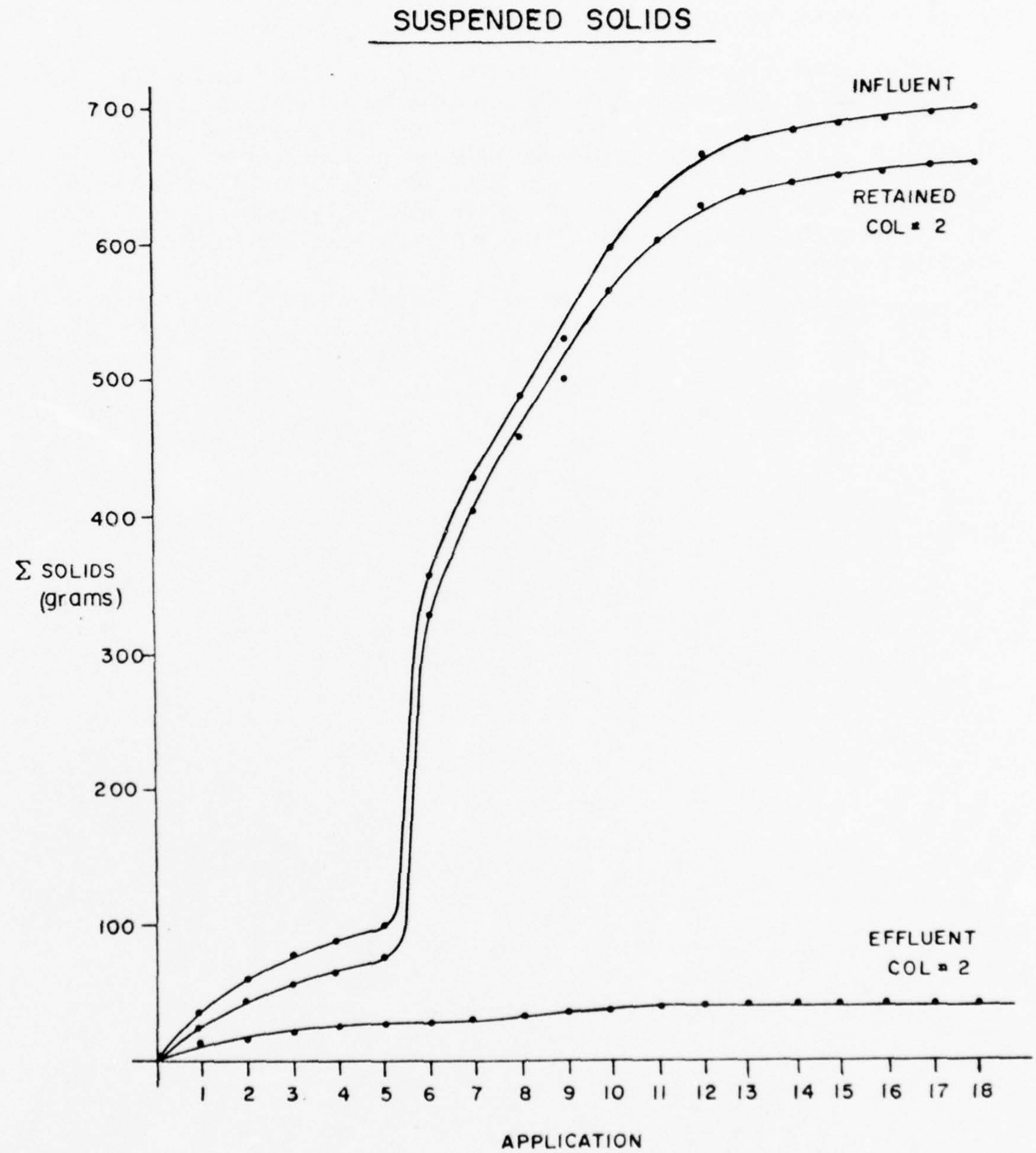


Figure 23. Mass balance, suspended solids--Column 2.

basin. The time between maintenance operations will depend on the system's operation and the wastewater's characteristics.

Startup problems will be limited mainly to filter operation. Initial startup of filters in a newly constructed facility will produce poor quality filtrate, caused by the washing of fines from filter media. Similar problems may be encountered if the filters are not used for a long period of time. A detention basin for filtered wastewater which can recirculate water to the equalization basin or filters will prevent suspended solids in the effluent that are in excess of regulatory agency limitations.

4 CONCLUSIONS

In response to the study objective, it was determined that:

1. Sufficient data were collected during this field evaluation to formulate design criteria for a centralized washing facility and wastewater treatment system based on CERL concepts.

2. Intermittent sand filtration of settled washrack wastewater can produce a better quality of effluent than that required by regulatory agencies.

3. The organic content of washrack wastewaters was generally low in the pilot study. Assuming normal BOD to COD relationships, organic content of the effluent from intermittent sand filters will be substantially below regulatory agency limitations.

Other conclusions were drawn relative to the ongoing CERL study of washrack wastewater recycling:

1. The column filters having 3.5 ft (1.05 m) of filter media (No. 2 and No. 3) generally produced a better quality filtrate than the two filters having 2 ft (.6 m) of media.

2. Oil and grease caused by occasional spills, leaks, or dumps of petroleum products during washing operations must be removed from washrack wastewaters.

3. Fort Drum native sand may be used as a filter media; however, its use would require careful monitoring and perhaps some processing after suitable deposits were located.

4. Applying 3 in. (7.6 cm) of wastewater to filters produced a better quality effluent than the 6-in. (15.2-cm) application.

5. Up to three applications of 3 in. (7.6 cm) of wastewater per day may be made to intermittent sand filters.

Because research time was short, there was insufficient data for:

1. Confidently predicting operation and maintenance characteristics of the proposed treatment scheme.

2. Determining the effect of intermittent sand filtration on a washrack wastewater containing substantial soluble organic content.

5 RECOMMENDATIONS

On the basis of this study, it is recommended that a washrack wastewater treatment facility like that proposed in Appendix B of this report be built at Fort Drum.

APPENDIX A:

USEPA PERMIT REQUIREMENTS (ABSTRACTED FROM USEPA NPDES DISCHARGE PERMIT NO. NY0026905)

General

The Regional Administrator of Region II of the U.S. Environmental Protection Agency, pursuant to authority by Section 1342 of the Federal Water Pollution Control Act Amendments of 1972, has issued a National Pollution Discharge Elimination System (NPDES) permit on vehicle washrack wastewater discharges at Fort Drum. The permit, which bears an effective date of 31 October 1974 and expires on 1 July 1977, contains the following provisions:

1. Location of Washrack Effluent Discharges

   a. Discharge 001 designates the wastewaters from Fort Drum washracks that empty into Plesant Creek at latitude 44°02'45" and longitude 75°46'15". This covers washracks whose effluents discharge directly or indirectly into St. James Lake adjacent to the Leray mansion on post.

   b. Discharge 002 designates the wastewater from Fort Drum washracks at latitude 44°02'45" and longitude 75°44'0" that discharge via surface drainage channels into the headwaters of Pleasant Creek (washracks 2090, 2091, 2092, and 2093).

2. Effluent Limitations

At the two designated discharge points, effluent from existing or proposed washrack wastewater treatment facilities must meet the quality criteria shown in Table [A1]. In addition, the permit specifies minimum monitoring requirements as described in Table [A2]. For new treatment facilities, the permit specifies an interim effluent discharge requirement of virtually complete removal of settleable solids, no discharge of floating solids or visible foam, and the performance of the minimum monitoring requirements as previously described. The interim effluent discharge requirements are applicable from the effective date of the permit through the date on which the new treatment facilities become operational.

3. Schedule of Compliance

The permit states that by 30 April 1975 the installation shall submit an Engineering and Facility Plan for achieving the required

Table [A1]

Effluent Requirements for Washrack Wastewater Discharges

Physical or Chemical Parameter	Concentration or Value
pH	6.0 to 9.0
5-Day Biochemical Oxygen Demand (BOD)*	
30-Day Average	30 mg/ℓ
7-Day Average	45 mg/ℓ
Grease and Oil*	
30-Day Average	10 mg/ℓ
7-Day Average	15 mg/ℓ
Suspended Solids*	
30-Day Average	30 mg/ℓ
7-Day Average	45 mg/ℓ

*Whichever is more stringent
Additional requirement: no discharge of floating solids or visible foam.

Table [A2]

Minimum Effluent Monitoring Requirements

Physical or Chemical Parameter	Measurement Frequency	Sample Type
Total Flow, mgd	Continuous	N/A
BOD_5, mg/ℓ	Once Per Week	Grab
Settleable Solids, mg/ℓ	Once Per Week	Grab
Suspended Solids, mg/ℓ	Once Per Week	Grab
pH	Once Per Week	Grab
Grease and Oil, mg/ℓ	Once Per Week	Grab

effluent limitations by 1 July 1977. The schedule of compliance is to include the following:

a. The completion date of final plans and specifications for the treatment facility.

b. The construction start date.

c. The construction completion date.

d. The date the treatment facilities will become operational. Within 14 days following each date specified on the above schedule, a report to the regional administrator shall be made detailing compliance or noncompliance.

APPENDIX B:

DESIGN CRITERIA

General

Figure B1 is a schematic of washing and wastewater treatment facilities recommended by CERL in Technical Report E-80[3] and in this report. Figure B2 illustrates the recommended scheme for treating wastewater from centralized wash facilities at Fort Drum, NY. Design criteria for the facilities described in Figures 1 and 2 are presented in CERL Technical Report E-80 and in the Design Calculations for Wastewater Treatment Components section of this appendix.

Vehicle Wash Facility

Tracked Vehicles

The tracked-vehicle wash facility will be sized to process a maximum of 400 vehicles in any 48-hour period and will consist of a vehicle preparation area for interior cleaning and an exterior wash area. The vehicle preparation area will accommodate 12 interior wash stations, each having a tower-supported, low-volume, low-pressure hose. Receptacles for the deposition of solid waste will be provided. The exterior wash area will accommodate six wash stations, each having two tower-supported hoses per station.

Wheeled Vehicles

The wheeled-vehicle wash facility will be sized to process a maximum of 1000 rubber-tired vehicles in any continuous 48-hour period. The facility will include a vehicle preparation area having 16 interior wash stations, each with one tower-supported wash hose. Vehicle exteriors will be washed at three automated fixed-nozzle exterior wash stations, each of which can process 20 vehicles per hour.

Wastewater Treatment Facility

Removal of Bulk Suspended Solids and Free Oil

To remove bulk suspended solids and free oil, each vehicle wash

[3] *Vehicle Washing Operations and Wastewater Discharges, Fort Drum, NY, Findings and Recommendations*, Technical Report E-80/ADA026173 (CERL, June 1976).

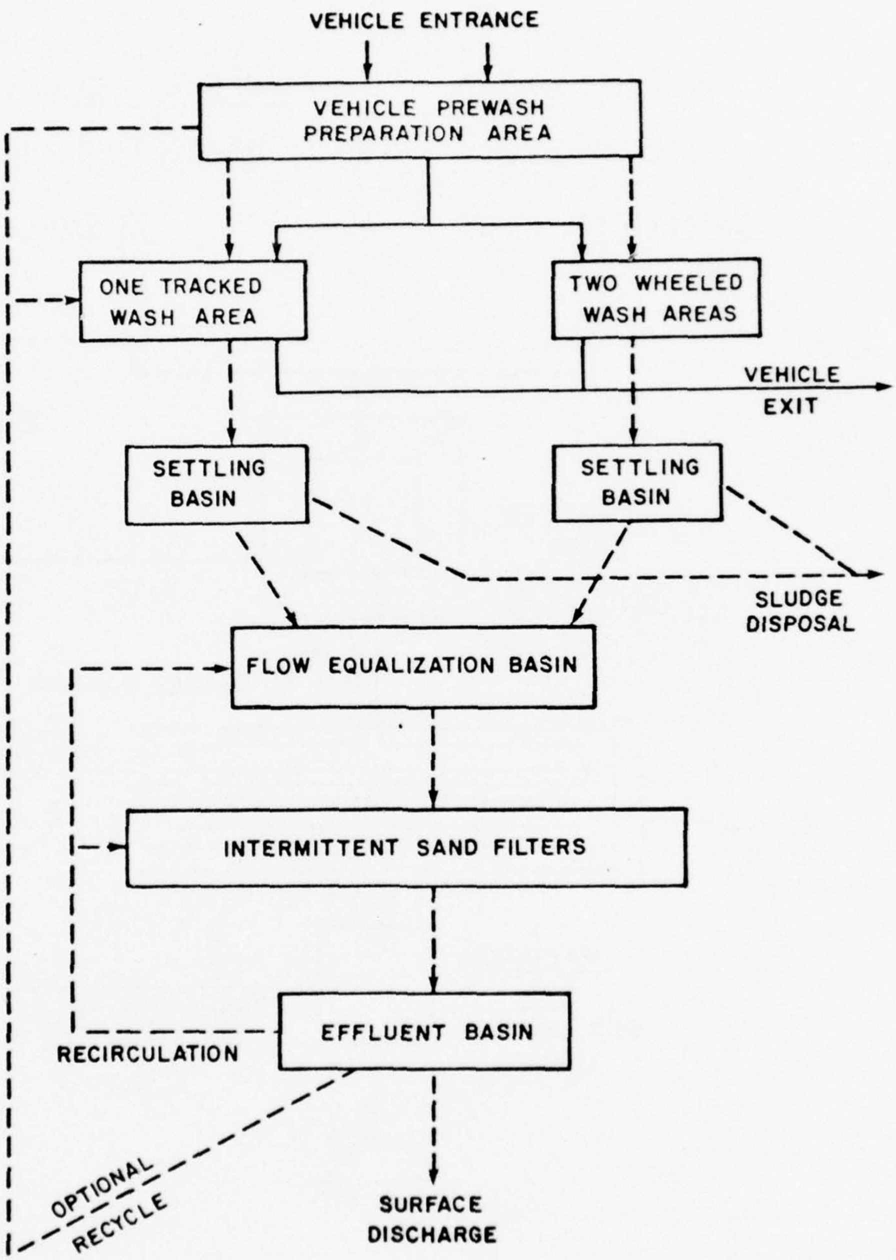


Figure B1. Recommended washing and wastewater treatment facilities at Fort Drum, NY.

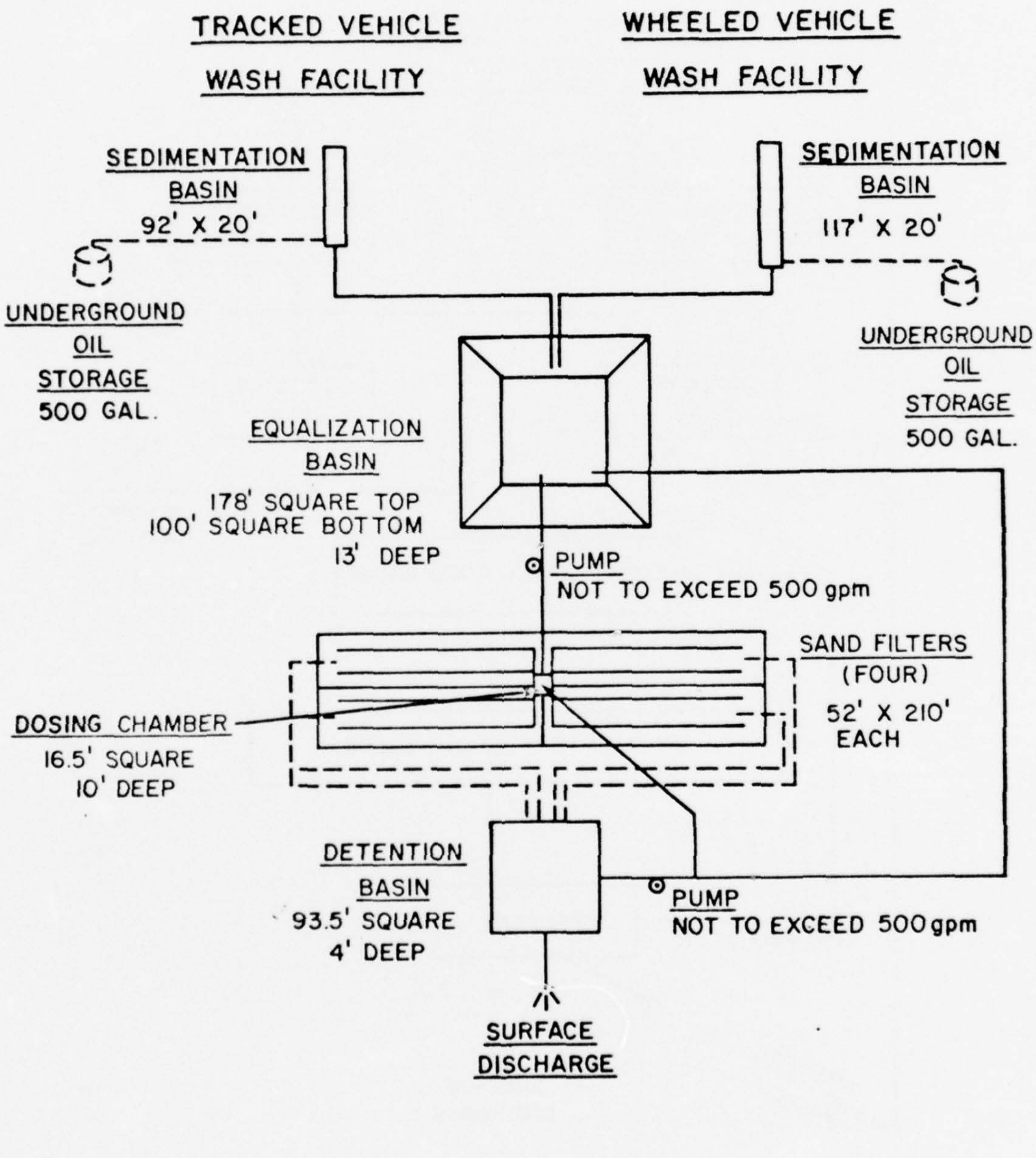


Figure B2. Washrack wastewater treatment.

area will have a reinforced concrete settling basin sized to allow for a minimum of 2 hours detention time in addition to design sediment storage requirements. The latter volumes can be assigned by allowing 0.1 cu ft (.002 m^3) and 1.0 cu ft (.02 m^3) of accumulated sediment for wheeled and tracked vehicles washed, respectively. The basin will be drained to the level of the design sludge zone; collected sediment will be removed either by a front-end loader (requiring a sedimentation basin with a sloped forebay area) or by external pumping to another vehicle.

For free oil separation, the sedimentation basins must allow for the removal of 100-micron diameter oil globules having a specific gravity of 0.99 at a temperature of 10°C. Dimensional characteristics of the basins shall conform to criteria recommended by the American Petroleum Institute.[4] Collected free oils can be removed by mechanical floating oils skimmers or any device capable of continuously removing a minimum of 1.0 gal (3.8 ℓ) of oil per hour.

Wastewater Flow Equalization

Wastewater flow will be equalized by a lined earthen basin having an active storage capacity of 1 million gal (3.8 million ℓ); this amount corresponds to the wastewater volume produced over the peak 2-day washing period. To allow for accumulations of fine sediment, a dead storage volume amounting to approximately 15 percent of the active storage must also be provided. Basin side slopes of one to three (rise to run) are recommended unless superseded by soil test results to determine embankment stability. The basin will have an emergency spillway designed to pass stormwater flows produced by a 10-year frequency storm. To safeguard against overtopping, a minimum freeboard of 2 ft (.6 m) above the spillway elevation at design flow will be included in the overall basin depth.

Intermittent Sand Filters

The intermittent sand filters will be sized on the basis of a maximum application rate of 245,000 gal (927,426 ℓ) of wastewater per day. Each of the four equal-sized filters to be provided will receive a controlled dose of 3 in. (7.6 cm) of wastewater every 8 hours. A central siphon-operated dosing chamber will be employed to deliver each filter dose in approximately 20 min. Wastewater will be pumped from the equalization basin to the dosing chamber at a rate not to exceed 50 percent of the siphon chamber discharge rate.

Each filter will consist of 36 in. (.9 m) of washed sand meeting all New York State Public Health Service specifications for filter

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[4] *Manual on Disposal of Refinery Wastes*, Vol I, "Liquid Wastes" (American Petroleum Institute, 1969).

sand except that the Effective Size (D_{10}) shall range between 0.2 and 0.4 mm. The filter sand will be underlain by selected course material containing an underdrainage system designed in accordance with recommendations contained in the American Society of Civil Engineering's *Manual of Engineering Practice No. 36*.[5] Each filter will be enclosed within reinforced concrete walls of 9-in. (22.8-cm) minimum thickness of appropriate footings. A minimum freeboard of 12 in. (.3 m) above the level of the sand will be provided; no bottom or bottom liner will be required.

Filter Effluent Detention Basin

The filter effluent will be discharged into a lined earthen basin sized to contain the effluent volume produced during the maximum day of filter operation. Pumps will recirculate the effluent either to the equalization basin or to the filter dosing chamber. Unrecirculated effluent volumes will be discharged to surface drainage after passing through a flow monitoring device. The basin will be a source of recycled water for the washing operation if economically and environmentally necessary.

Design Calculations for Wastewater Treatment Components

Maximum Wastewater Flows

1. Tracked vehicle wash facility

a. Vehicle preparation area--10 gpm (38 ℓ/min) per station @ 12 stations = 120 gpm (454 ℓ/min)

b. Exterior wash facilities--30 gpm (114 ℓ/min) per hose @ two hoses per station @ 6 stations = 360 gpm (1363 ℓ/min)

c. Maximum flow generated = 480 gpm (1817 ℓ/min)

2. Rubber-tired vehicle wash facility

a. Vehicle preparation area--10 gpm (38 ℓ/min) per station @ 16 stations = 160 gpm (606 ℓ/min)

b. Exterior washing facilities--185 gpm (700 ℓ/min) per station @ three stations = 555 gpm (2101 ℓ/min)

c. Maximum flow generated = 715 gpm (2707 ℓ/min)

[5] *Manual of Engineering Practice No. 36, Sewage Treatment Plant Design* (American Society of Civil Engineering, 1959).

Minimum Wastewater Flows

Zero gpm (0 ℓ/min) from all areas.

Average Flow Over Washing Period

1. Tracked vehicle wash facility

a. Maximum washing period--200 vehicles per 24 hours @ 0.5 hours per vehicle per prep station @ 12 stations = 8.33 hours per day

b. Assumed percentage use--67 percent for vehicle prep area; 90 percent for exterior wash area

c. Average flow = 24,300 gal (91 986 ℓ) per each wash hour

2. Wheeled-vehicle wash facility

a. Maximum washing period--500 vehicles per day @ 20 vehicles per hour per exterior wash station @ three stations = 8.33 hours

b. Assumed percentage use--90 percent for vehicle prep area; 90 percent for automated exterior wash facilities

c. Average flow--38,610 gal (146 155 ℓ) per wash hour

Wastewater Characteristics

On the basis of observations and data collected during the summers of 1975 and 1976 at Fort Drum, wastewater characteristics for treatment unit design are assumed to be as follows:

Average volume of sediment deposited per tracked vehicle--1.0 cu ft (.02 m^3)

Average volume of sediment deposited per rubber-tired vehicle--0.1 cu ft (.002 m^3)

Average free oil concentration--20 mg/ℓ

Sedimentation Basin Sizing

1. Tracked vehicle wash facility

a. Sludge storage requirements

$$\frac{4800 \text{ vehicles}}{\text{season}} \times \frac{1.0 \text{ cu ft}}{\text{vehicle}} = 480 \text{ cu ft}$$

$$\left(\frac{4800 \text{ vehicles}}{\text{season}} \times \frac{.02 \text{ m}^3}{\text{vehicle}} = 96 \text{ m}^3\right)$$

Allow for a sludge storage volume of 1600 cu ft (45 m^3) with sludge removal carried out three times per season.

b. Volume requirements for design sediment storage plus 2 hours detention at design average flow:

$$\text{Volume total} = V_T = 1600 \text{ cu ft} + V_2$$

$$(V_T = 45 \text{ m}^3 + V_2)$$

$$\text{Volume of 2-hour detention} = V_2 = \frac{24,300 \text{ gal}}{\text{hr}} \times \frac{2 \text{ hr}}{1}$$

$$\times \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = 6497 \text{ cu ft}$$

$$\left(V_2 = \frac{91\ 986\ \ell}{\text{hr}} \times \frac{2 \text{ hr}}{1} \times \frac{.02 \text{ m}^3}{28.3\ \ell} = 130 \text{ m}^3\right)$$

c. Requirements for oil separator chamber

(1) Wastewater characteristics

(Q_T) = Design average flow = $\frac{24,300 \text{ gal}}{\text{hr}}$ (54.2 cfm)

T = 10°C = $\left(\frac{89\ 910\ \ell}{\text{hr}}[2 \text{ m}^3/\text{min}]\right)$

Specific gravity (Sw) = 0.998

Absolute viscosity (μ) = 1.3 centipoises

Maximum allowable horizontal velocity (V_H);

Velocity horizontal = $V_H = 15v_t$ (2.0 fpm [.9 m/min] maximum)

(2) Oil globule characteristics

Diameter (D) = 0.015 m[3]

Specific gravity (S_o) = 0.9078

v_t = rate of rise of oil globules under specified conditions (fpm)

$$v_t = 0.0241 \left(\frac{Sw - So}{\mu}\right)$$

$$= (0.0241)\ \frac{(0.998 - 0.0978)}{0.0130} = 0.167 \text{ fpm } (.05 \text{ m/min})$$

Maximum horizontal velocity (V_H)

$V_H = 15\ v_t = 15 \times 0.167 = 2.5$ fpm (.76 m/min)

Use 2.5 fpm (.76 m/min)

Design factor (F)[6]

$$\frac{V_H}{v_t} = \frac{2.5}{0.167} = 15$$

F = 1.67

Minimum cross-sectional area (Ac)

$$Ac = \frac{Q_T}{V_H} = \frac{54.2}{2.5} = 21.7 \text{ ft}^2$$

d. Sludge storage depth

Assume width W = 20 ft (6 m)

Volume sludge = V_{SL} = 1600 cu ft (45 m^3) = (20)

$$(40 + \frac{3\ dt + 40}{2})\ (d = \text{depth})$$

Depth sludge = d_{SL} = 1.0 ft (.3 m)

6 *Manual on Disposal of Refinery Wastes*, Vol 1, "Liquid Wastes" (American Petroleum Institute, 1969), Chapter 5, p 5-5. "F" is an empirical design factor compensating for affects of turbulence in oil separation basins.

e. Basin depth

Volume total = V_{TOT} = 8100 cu ft (229 m^3) = (20)

$$\left(\frac{40 + 3d + 40}{2}\right) \text{ (d = depth)}$$

Depth = d ≈ 8.0 ft (2.4 m)

Make d = 10 ft (3 m) which allows for 2.0 ft (.6 m) of freeboard.

Basin length ≈ L_1 = 40 + 3d = 40 + (3)(10) = 70 ft (21 m)

f. Oil separation chamber

Minimum cross-sectional area required--21.7 sq ft (2.02 m^2)

Using two channels, each 10 ft (3 m) wide by 3 ft (.9 m) deep.

$$V_H = \frac{Q_T}{A_c} = \frac{54.2 \text{ cfm}}{60 \text{ sq ft}} = 0.9 \text{ fpm}$$

$$\left(V_H = \frac{Q_T}{A_c} = \frac{1.53 \text{ m}^3/\text{min}}{5.6 \text{ m}^2} = .27 \text{ m/min}\right)$$

$$\frac{V_H}{v_t} = \frac{0.9}{0.167} = 5.4_1 \qquad F = 1.37$$

$$\text{Oil chamber length} \approx L_2 = \frac{F(V_H)d}{v_t} = \frac{(1.37)(0.9)(3)}{(0.167)}$$

$$= 22 \text{ ft } (6.7 \text{ m})$$

Total length of basin = 92 ft (27.6 m)

2. Wheeled-vehicle wash facility

a. Sludge storage requirements

$$\frac{17646 \text{ vehicles}}{\text{season}} \times \frac{0.1 \text{ cu ft } (.002 \text{ m}^3)}{\text{vehicle}} = 1765 \text{ cu ft } (50.0 \text{ m}^3)$$

Allow for a sludge storage volume of 1800 cu ft (51 m^3) with sludge removal once per season.

b. Volume requirements for design sediment storage plus 2 hours detention at design average flow

$$VT = 1800 \text{ cu ft} + V_2$$

$$V_2 = \frac{38{,}610 \text{ gal}}{\text{hr}} \times \frac{2 \text{ hr}}{1} \times \frac{1 \text{ cu ft}}{7.48 \text{ gal}} = 10{,}324 \text{ cu ft}$$

$$(V_2 = \frac{146\ 155\ \ell}{\text{hr}} \times \frac{2 \text{ hr}}{1} \times \frac{.02 \text{ m}^3}{28.6\ \ell} = 204 \text{ m}^3)$$

$$V_T + 1800 + 10{,}324 = 12{,}124 \text{ cu ft } (343.\ \text{m}^3)$$

c. Requirements for oil separation chamber

(1) Wastewater characteristics

$$\text{Design average flow} = \frac{38{,}610 \text{ gal}}{\text{hr}} \ (86.1 \text{ cfm})$$

$$T = 10°C = (\frac{146\ 155\ \ell}{\text{hr}}\ [2.44 \text{ m}^3/\text{min}])$$

Specific gravity (Sw) = 0.998

Absolute viscosity (μ) = 1.3 centipoises

Maximum allowable horizontal velocity (V_H);

$V_H = 15v_t$ (3.0 fpm [.9 m/min] maximum

(2) Oil globule characteristics

Diameter (D) = 0.015 m^3

Specific gravity (So) = 0.9078

v_t = rate of rise of oil globules under specified conditions (fpm)

v_t = 0.167 fpm (.05 m/min)

Use the same general configuration for the basin.

d. Sludge storage depth

Assume width = 20 ft (6 m)

Volume sludge = V_{SL} = 1800 cu ft = $20(\frac{40 + 3d + 40}{2})$ (d = depth)

Depth sludge = d_{SL} = 2.1 ft (.64 m)

e. Basin depth

Volume total = V_{TOT} = 12,124 = $(20)(\frac{40 + 3d + 40}{2})$ (d = depth)

depth = d = 10.8 ft (3.3 m)

Make d = 13 ft (4.0 m) which allows for approximately 2 ft (.6 m) of freeboard.

Basin Length = L_1 = 40 + 3d = 40 + (3)(13) = 79 ft (24.1 m)

f. Oil separation chamber

Minimum cross-sectional required (Ac)

$$Ac = \frac{QT}{V_H} = \frac{86.1}{2.5} = 34.4 \text{ sq ft } (3.2 \text{ m}^2)$$

Using two channels each 10 ft (3 m) wide by 3 ft (.9 m) deep

$$V_H = \frac{Q_T}{Ac} = \frac{86.1}{60} = 1.44 \text{ fpm } (.43 \text{ m/min})$$

$$\frac{V_H}{v_t} = \frac{1.44}{0.167} = 8.6, \quad F = 1.47$$

Oil chamber length = $L_2 = \frac{F(V_H)d}{v_t}$ = (1.47)(8.6)(3) = 38 ft (11.6 m)

Total length of basin = 117 ft (35.7 m)

g. Oil removal equipment

(1) Tracked vehicle wash facility

(a) Oil removal rate--assume 100 percent removal

$$\frac{20\ \text{mg (oil)}}{\ell} \times \frac{\text{m}\ell\ \text{(oil)}}{0.9078\ \text{gr}} \times \frac{1\ \text{gr}\ (.9\ \ell)}{1000\ \text{mg}} \times$$

$$\frac{1\ \text{gal}\ (3.7\ \ell)\ \text{oil}}{3.79\ \ell\ \text{(oil)}} \times \frac{3.79\ \ell}{\text{gal}} \times \frac{1\ \ell}{1000\ \text{m}\ell} \times$$

$$\frac{24{,}300\ \text{gal}\ (89\ 910\ \ell)}{\text{hr}} = 0.54\ \text{gal}\ (.16\ \ell)\ \frac{\text{oil}}{\text{hr}}$$

Each unit must be capable of removing a minimum of 0.5 gal of oil per hour. (Design for 5 to 10 gal (13.7 to 37.8 ℓ) of oil removal per hour for each unit to handle peak oil loadings resulting from spills or dumps.)

(b) Oil storage capacity

At maximum usage

$$\frac{0.54\ \text{gal}}{\text{hr}} \times \frac{16.7\ \text{hr}}{1} = 9\ \text{gal}$$

$$\left(\frac{2\ \text{gal}}{\text{hr}} \times \frac{16.7\ \text{hr}}{1} = 33.3\ \ell\right)$$

Use a 500-gal (1893 ℓ) underground storage tank.

(2) Wheeled vehicle wash facility

(a) Oil removal rate

$$\frac{0.54\ \text{gal}}{\text{hr}} \times \frac{38{,}610}{24{,}300} = 0.9\ \text{gal/hr}$$

$$\left(\frac{2\ \text{gal}}{\text{hr}} \times \frac{38{,}610}{24{,}300} = 3.3\ \ell/\text{hr}\right)$$

Each unit must be capable of removing a minimum of 1 gal (3.7 ℓ) of oil per hour. (Design for 5 to 10 gal (18.9 to 37.8 ℓ) of oil removal for each unit.)

(b) Oil storage capacity

At maximum usage

$$\frac{0.9\ \text{gal}}{\text{hr}} \times 16.67\ \text{hr} = 15\ \text{gal}$$

$$\left(\frac{3.4\ \ell}{hr} \times 16.67\ hr = 56.7\ \ell\right)$$

Use a 500 gal (1893 ℓ) underground storage tank.

Alternative Sedimentation Basin Design

An alternative to the sloped forebay sedimentation basin design described previously would be one that is rectangular in plan with sediment removal accomplished by external pumping, such as by a Vac-All truck.

1. Tracked vehicle wash facility

a. Sludge storage requirements: 1600 cu ft (45.3 m^3) with removal carried out three times per season.

b. Volume requirements for design sediment storage plus 2 hours detention at design average flow.

Volume required = 1600 cu ft + 6497 cu ft

= approximately 8100 cu ft

= (45.3 m^3 + 184 m^3 = approximately 229.3 m^3)

Try a total depth of 10 ft (3 m) with 2 ft (.6 m) of freeboard and a length/width ratio of approximately 2.

$(8)(2W)(W) = 8100$

$W^2 = 506.3$

$W = 22.5$ ft (6.86 m) (Make W = 20 ft [6.1m])

$160\ L = 8100$

$L = 51$ ft (15.5 m) (Make L = 50 ft [15.2 m])

c. Uniform sludge depth

$$d_{SL} = \frac{1600}{(50)(20)} = 1.6 \text{ ft } (.49 \text{ m})$$

d. Overflow rate = $\frac{24{,}300 \text{ gal}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{1}{(50 \text{ ft})(20 \text{ ft})}$

$$\left(= \frac{91\ 986\ \ell}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{1}{(15.2 \text{ m})(6.1 \text{ m})}\right)$$

$$= 583 \text{ gal/day/sq ft } (= 23\ 810\ \ell/\text{day/m}^2)$$

e. For wastewater sediment assumed to have a specific gravity of 1.67 and a diameter of 100 microns at a water temperature of 10°C.

$$\text{Settling velocity} = \frac{0.009 \text{ ft}}{\text{sec}} (.0027 \text{ m})$$

$$\text{Minimum surface area required} = \frac{24{,}300 \text{ gal}}{\text{hr}} \times \frac{\text{cu ft}}{7.48 \text{ gal}}$$

$$\times \frac{1 \text{ hr}}{3600 \text{ sec}} \times \frac{1 \text{ sec}}{0.009 \text{ ft}} = 100 \text{ sq ft}$$

$$\left(\frac{91\ 986\ell}{\text{hr}} \times \frac{0.28 \text{ m}^3}{28.3\ \ell} \times \frac{1 \text{ hr}}{3600 \text{ sec}} \times \frac{\text{sec}}{.0027 \text{ m}} = 9.5 \text{ m}^2\right)$$

Therefore, basin surface area as computed is adequate.

2. Wheeled vehicle wash facility

a. Sludge storage requirements: 1800 cu ft (51 m^3) with sludge removal once per season.

b. Volume requirements for design sediment storage plus 2 hours detention at design average flow

$$\text{Volume required} = 1800 \text{ cu ft} + 10{,}324 \text{ cu ft} = 12{,}124 \text{ cu ft}$$

$$(= 51 \text{ m}^3 + 292 \text{ m}^3 = 343 \text{ m}^3)$$

Try a total depth of 12 ft (3.6 m) with 2 ft (.61 m) of freeboard and a length/width (L/W) ratio of approximately 2.

$$(10)(2W)(W) = 12{,}124$$

$$W^2 = 606.2$$

$$W = 24.6 \text{ ft } (7.5 \text{ m}) (\text{make } W = 25 \text{ ft } [7.6 \text{ m}])$$

$$250\ L = 12{,}124$$

$$L = 48.5 \text{ ft } (14.8 \text{ m}) \ (\text{make } L = 50 \text{ ft } [15.2 \text{ m}])$$

c. Uniform sludge depth

$$\text{Sludge depth} = d_{SL} = \frac{1800}{(50)(25)} = 1.4 \text{ ft } (.43 \text{ m})$$

d. $$\text{Overflow rate} = \frac{38{,}610 \text{ gal}}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{1}{(50 \text{ ft})(25 \text{ ft})}$$

$$= 741 \text{ gal/day/sq ft}$$

$$\left(= \frac{146\ 155\ \ell}{\text{hr}} \times \frac{24 \text{ hr}}{\text{day}} \times \frac{1}{(15.2 \text{ m})(7.6 \text{ m})}\right.$$

$$\left. = 30\ 364\ \ell/\text{day/m}^2 \right)$$

e. Minimum surface area requirements

$$\frac{38{,}610 \text{ gal}}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} \times \frac{1 \text{ cu ft}}{7.48 \text{ gal}} \times \frac{1 \text{ sec}}{0.009 \text{ ft}} = 159.3 \text{ sq ft}$$

$$\left(\frac{142\ 857\ \ell}{\text{hr}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} \times \frac{.02 \text{ m}^3}{27.6\ \ell} \times \frac{1 \text{ sec}}{0.0027 \text{ m}} = 14.3 \text{ m}^2\right)$$

Therefore, basin surface area as computed is adequate.

f. Equalization basin sizing

Total average flow from washracks = 24,300 + 38,610 = 62,910 gal/hr (238 140 ℓ/hr) of washing

Total volume of flow over maximum 2 days of washing =

$$\frac{62{,}910 \text{ gal}}{\text{hr}} \times \frac{16.67 \text{ hr}}{1} = 1{,}049{,}000 \text{ gal}$$

$$\left(\frac{238\ 140\ \ell}{\text{hr}} \times \frac{16.67 \text{ hr}}{1} = 3\ 969\ 794\ \ell\right)$$

Allow filter to treat a volume of 82,000 gal (310 404 ℓ) per 8-hour period or 164,000 gal (620 808 ℓ) per 16-hour period. To allow for stormwater accumulations and recycling of filter effluent through the basin, allow for an active storage in the basin of 1,000,000 gal (3 785 412 ℓ).

Allowing 2 ft (.6 m) depth for sediment storage, try a base width of 100 sq ft (9.3 m^2) and allow 3 ft (.9 m) of freeboard (see Figure B3).

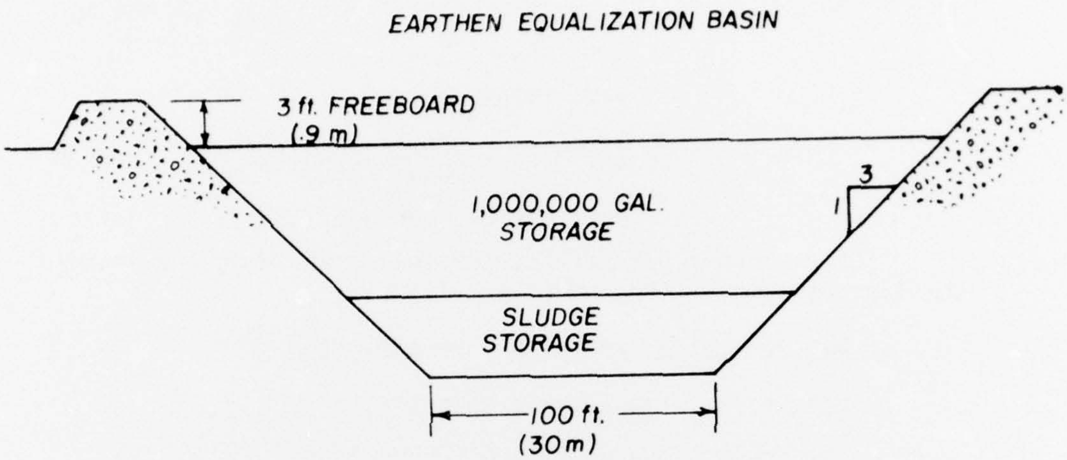

Figure B3. Earthen equalization basin.

Sediment storage @ d_{SL} + 2.0 ft (.6 m)

$$V_{SL} = \frac{(112)^2 + (100)^2}{2} \times 2 = 22{,}544 \text{ cu ft } (638.4 \text{ m}^3)$$

Depth of active storage

$$\frac{(112)^2 + (112 + 6d)^2}{2} d = \frac{1{,}000{,}000 \text{ gal}}{7.48} = 133{,}690 \text{ cu ft}$$

$$\left(\frac{(112)^2 + (112 + 6d)^2}{2} d = \frac{3\ 785\ 412\ \ell}{7.48} = 3785.7 \text{ cu m}\right)$$

d = 7+ ft (2.1 m) (make d = 8 ft [2.4 m])

Use 13-ft (3.9-m) deep basin

g. Dosing chamber

Maximum of three applications per day at a 3-in. (7.6-cm) depth

Filter area = 43,680 sq ft (4058 m²)

Use four filters of 10,920 sq ft (1014.5 m²) each

$$43{,}680 \text{ sq ft} = 7.485 \text{ gal cu/ft} \times \frac{3 \text{ in.}}{12 \text{ in./ft}} \times \text{three ap-}$$

plications per day = 245,209 gal/day

$$(4058 \text{ m} \times \frac{28.3\ \ell}{.0283\ \text{m}^3} \times \frac{7.6 \text{ m}}{100 \text{ cm/m}} \times \text{three}$$

applications per day = 925 224 ℓ/day)

For three applications, the volume would be one-third of the flow divided by the number of filters.[7]

245,209 gal x 1/2 x 1/4 = 20,434 gal

(928 217 ℓ x 1/3 x 1/4 = 77 351 ℓ)

$$20{,}434 \text{ gal} \times \frac{1 \text{ cu ft}}{7.485 \text{ gal}} = 2{,}730 \text{ cu ft}$$

$$(77\ 351\ \ell \times \frac{.001\ \text{m}^3}{1\ \ell} = 77\ \text{m}^3)$$

For a 10-ft (3-m) deep chamber square

$\sqrt{2730 \text{ cu ft}/10 \text{ ft}} = 16.5 \text{ ft}$ ($\sqrt{77.3\ \text{m}^3/3\ \text{m}} = 5.0$ m)

Therefore, the dosing chamber size would be 16.5 ft (5.0 m) x 16.5 ft (5.0 m) x 10 ft (3 m) deep.

The rate of discharge from the dosing chamber at average head is usually about 1 cfs (.028 m^3/sec) per 5000 sq ft (465 m^2) of filter area dosed.[8]

$$\text{Four filters @ } 10{,}920 \text{ sq ft } (1014.5\ \text{m}^2) = \frac{10{,}920 \text{ sq ft}}{5000 \text{ sq ft/cfs}}$$

= 2.184 cfs

$$(= \frac{1014.5\ \text{m}^2}{465\ \text{m} / .028\ \text{m}^3/\text{sec}} = .062\ \text{m}^3/\text{sec})$$

Use 2.0 cfs (.056 m^3/sec) for discharge sizing from dosing chamber.

$$\frac{20 \text{ cfs}}{2.228 \times 10^{-3} \text{ cfs/gpm}} = 897.6 \text{ gpm}$$

[7] *Sewage Treatment Plant Design*, No. 36 (ASCE Manual, 1959), p 181.
[8] *Sewage Treatment Plant Design*, p 181.

$$\frac{.056 \text{ m}^3/\text{sec}}{6.3 \times 10^{-5} \text{ m}^3/\text{sec}/3.78 \text{ ℓ/min}} = 3{,}398 \text{ ℓ/min}$$

Therefore, time to discharge chamber =

$$\frac{20{,}434 \text{ gal } (77\ 351 \text{ ℓ})}{897.6 \text{ gpm } (3398 \text{ ℓ/min})} = 23 \text{ min}$$

Influent to dosing chamber from equalization basin should be less than the effluent for good siphon operation; therefore, considering a 2.0 cfs (.056 m^3/sec) discharge, the influent pump should be about 1.0 cfs (.028 m^3/sec).

Intermittent Sand Filters

The filter area is divided into four equal rectangular segments with dimensions of 210 ft (64 m) by 52 ft (15.8 m). The walls should be ≥ 9-in. (22.8-cm) thick reinforced concrete on footings. No bottom or bottom liner will be required. The sand will be within the range of 40 mm $\leq x \geq$ .22 mm layed in a 3-ft (.9-m) bed with a minimum of 1 ft (.3 m) of freeboard. The underdrain collection system will be the manifold type, using open jointed tile.[9]

Detention Basin

A detention basin will receive the water from the filters. The basin will have a volume of 35,000 cu ft (991 m^3) with a depth of < 4 ft (1.2 m)

$\sqrt{35{,}000 \text{ cu ft}/4 \text{ ft}} = 93.5$ ft if square $(\sqrt{991 \text{ m}/1.2 \text{ m}} = 28.5 \text{ m})$

Note: Site and/or pumping for return to equalization basin may require rectangular configuration.

Pumps will be required for recirculating wastewater to the equalization basins as required. Normal discharge is to surface drainage; however, this basin will be the source for recycling wastewater to the washing operation if future economics justify this option.

[9] E. W. Steel, *Water Supply and Sewage* (McGraw-Hill, 1960), Chapter 24.

APPENDIX C: FILTER SAND ANALYSES

I. Identification

Sample No.	Location
1	Vicinity of Washrack No. 2090 Fort Drum, NY
2	Wheeler - Sacks Airport, Southeast Fort Drum, NY
3	Wheeler - Sacks Airport, Northeast Fort Drum, NY
4	Flick Pit Clayton, NY

II. Mechanical Analysis

Sieve Size	(see Figure B1) Sample 1	Sample 2	Sample 3	(see Figure C1) Sample 4
3/8 in. (9.53 mm)	100.0			100.0
#4 (6.35 mm)	99.8			99.2
#10 (2.54 mm)	99.1	100.0	100.0	92.0
#20 (1.27 mm)	91.6	86.3	97.2	70.0
#40 (.64 mm)	42.8	39.1	64.5	36.1
#100 (.25 mm)	2.1	5.6	7.7	4.2
#200 (.13 mm)	0.7	0.3	1.9	1.4
Uniformity Coefficient	2.4	3.0	2.5	2.9
Effective Size (D_{10})	0.21	0.20	0.16	0.23

III. Specific Gravity

Sample No. 1 Specific Gravity = 2.61

No. 2 = 2.68

No. 3 = 2.61

No. 4 = 2.66

IV. Constant Head Permeability Test

Sample No.	*Natural Moisture Content (%)	*Dry Density (pcf)[kg/m³]	Coefficient of Permeability(cm/sec)
1	1.0	103.1 [1651.5]	2.1×10^{-2}
2	0.7	105.5 [1689.4]	4.3×10^{-2}
3	1.5	99.3 [1590.6]	5.6×10^{-3}
4	2.7	99.9 [1600.2]	1.2×10^{-2}

*Soil was compacted into the permeability apparatus (1/30 cu ft [.001 m^3] proctor mold) at the moisture content of the bag sample. The soil was placed in the mold in two layers and compacted with the standard proctor hammer at the rate of ten blows per layer.

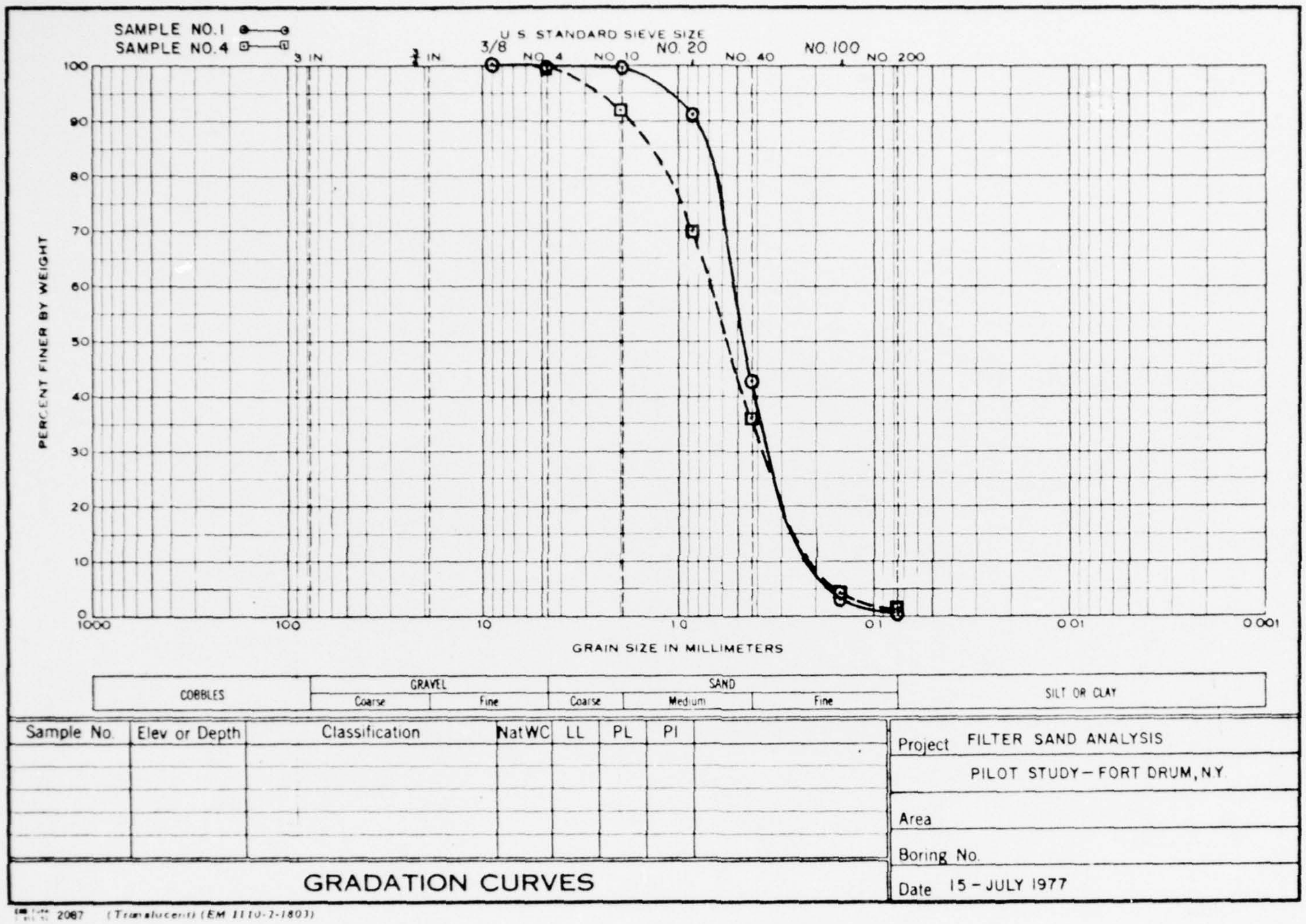

Figure C1. Sand gradation curves.

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